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STUDY REPORT
CAA-SR-91-15

**GLOBAL FORCE ALLOCATION MODEL
(GLOFAM) DEVELOPMENT AND
TECHNICAL DESCRIPTION**

JUNE 1991



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PREPARED BY
STRATEGY AND PLANS DIRECTORATE

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Prepared by

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GLOBAL FORCE ALLOCATION MODEL (GLOFAM) DEVELOPMENT AND TECHNICAL DESCRIPTION

STUDY
SUMMARY
CAA-SR-91-15

THE REASON FOR PERFORMING THIS STUDY was to provide the Army with a new analytical tool to support force planning by the Army Staff within the revised demands of current and future international security environments.

THE STUDY SPONSOR. This was an internal US Army Concepts Analysis Agency (CAA) research and development effort.

THE STUDY OBJECTIVE was to develop a flexible, fast-running, easy-to-understand model which will provide recommended force structures for multiple global requirements within imposed resource, policy, and other constraints.

THE MAIN ASSUMPTIONS of this work are:

- (1) The results of campaign simulations using the Concepts Evaluation Model (CEM) can be used to calibrate an effectiveness parameter in a linear programming model to provide an indicator of force performance.
- (2) Simple, effective, and acceptable techniques can be used to determine the contribution of weapon systems and land forces, including combat support (CS) and combat service support (CSS), to theater-level campaign simulations.

THE BASIC APPROACH used in this study was to develop a spreadsheet-based linear programming model which is flexible, fast-running, and user-friendly, and which addresses the essential elements and parameters of the force planning process.

THE PRINCIPAL ACCOMPLISHMENT of this work is the development of a force planning analytical tool which can be used as:

- (1) A screening tool prior to detailed analysis by campaign simulation, or other means, when time permits.
- (2) The main model for quick reaction analyses and force planning during periods of uncertainty.

The model can provide recommended force structure for:

- Given resource levels (manpower, money, lift, equipment).
- Given strategic objectives.
- Incorporation of modernized weapon systems and new force concepts.
- Support elements.

THE STUDY EFFORT was directed by MAJ John Dovich, Strategy and Plans Directorate.

COMMENTS AND QUESTIONS may be sent to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-SPF, 8120 Woodmont Avenue, Bethesda, Maryland 20814-2797.

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GLOBAL FORCE ALLOCATION MODEL (GLOFAM) DEVELOPMENT AND TECHNICAL DESCRIPTION

CHAPTER 1

INTRODUCTION/EXECUTIVE SUMMARY

1-1. PURPOSE. This report documents the Global Force Allocation Model (GLOFAM) development effort and provides a detailed technical description of the model. An illustrative analysis is included to demonstrate the model's operation and utility as a strategic planning tool. GLOFAM was designed with ease of use, responsiveness, and flexibility as key features. GLOFAM provides the Army with the capability to structure the deployable force by judiciously allocating budgetary and personnel resources. GLOFAM is formulated as a linear programming model which minimizes worldwide risk to national security subject to resource constraints. The product of model operation is an allocation of force configuration with corresponding cost and personnel end-strength values.

1-2. PROBLEM. GLOFAM will be used as an analytical tool to support decisions by the Army Staff concerning force planning and development. These decisions can be used to provide input into the Joint Strategic Planning System (JSPPS) and the Army Planning, Programming, Budgeting, and Execution System (PPBES). GLOFAM can be used to help address problems such as the following:

- a. What US Army conventional forces are required to meet acceptable force combat power criteria in a multitheater scenario?
- b. What US Army forces are achievable within budgetary, manpower, and other limitations?
- c. How can the Army build the most powerful constrained force?

Within this general framework, questions such as the following can be answered:

- How many and what type divisions are required in each potential theater of operations?
- What are the support packages (combat support, combat service support, and general support, including table of distribution and allowances (TDA)) required to sustain these divisions?
- What nondivisional combat units are required to enhance the combat power of these divisions?
- What should be the Active Component/Reserve Component (AC/RC) mix of these forces?
- How many personnel are required to man these forces?

- What are the peacetime recurring costs of these forces?
- What are the impacts of policy decisions on force cost and potential?

1-3. BACKGROUND. Since the end of World War II (WWII), the Army has been tasked to project the requirements for future forces in order to support the nation's global military strategy. The United States is now facing fundamental changes in the international scene, especially changes in the threat posed by the Soviet Union and the Warsaw Pact. Likewise, analytic force planning efforts must also undergo changes in order to meet the current and critical needs of the Army. Ongoing efforts in this area have indicated the need for analysis which:

- a. Addresses basic force planning criteria.** The analysis must be able to handle the fundamental questions of measuring force effectiveness and determining the resources required to field the force at a macro level of analysis. The goal is to develop a model which can be used for the first cut of force development. The output of this model will be used as the point of departure from which more detailed analysis can be done.
- b. Addresses global force requirements.** While the threat to national interests may appear to be decreasing from the Soviet Union and Warsaw Pact, significant threats continue to exist throughout the world, and new threats could arise at any time. At the operational level, these threats are represented as theaters. If there were only one theater, or if all theaters were subsets of a single theater, the ideal force would be easy to define. However, as can be readily appreciated, the widely divergent missions of the Army have a great impact on the structure of the ideal force. The model should have the capability to easily add or delete regional force requirements analyses. The problem of force design is further compounded by an uncertain future.
- c. Recognizes uncertainty.** Never more so than today, force planning is hampered by uncertainty. Almost all the factors which are involved in the force design and development process are in a transitory state at this time. Levels of funding, the location and size of threat, the support of allies, and even the role of the United States in the international community are very much open to question. At best, conflicting visions of the future can be evaluated according to their potential consequence to US interests and their likelihood. The model should be able to hedge against the unpredictability of the future.
- d. Recognizes the need for timeliness.** Timeliness is critical. Force planners are constantly required to provide timely answers to questions concerning the impact of changes in resource levels and other fundamental inputs of the force development process. These "what if" drills, as well as the sizable sensitivity analysis requirements caused by the numerous uncertainties which must be addressed, demand the use of a model which supports quick turnaround analysis.

1-4. APPROACH

a. Based on these requirements, the goal was to develop a model with the following characteristics to support the required analysis:

(1) User-friendly, especially for input/output operations. Due to uncertainty of data, the model will probably be frequently used for "what if" drills, and sensitivity analysis will be required to test the effect on the results of varying input parameters. Each analysis will involve multiple runs for minor changes of input. Input operations should therefore be easy to perform, and output, or run results, should be easy to understand.

(2) Fast running. Since each analysis will require multiple runs and timeliness is essential, it is important that model run time be kept to a minimum.

(3) Adaptable to changes in the number of theaters of operation or other force planning requirements. The model should be flexible enough to handle additions or deletions to the requirements for force structure regardless of the source of that requirement.

(4) Simple to understand. Since this model is being developed for macro, "first-cut" analysis with hopefully broad application, it is desirable that it have the credibility to inspire confidence in its use by Army force planners.

(5) Addresses a broad spectrum of force design factors using both subjectively and objectively measured inputs which are beyond the scope of combat simulation models.

b. Requirements, research, and previous experience with force design analysis led to the formulation of the problem as a linear programming model. Linear programming is an ideal medium for conducting force design. Force designers generally understand formulation assumptions and are receptive to results from linear programming models because these models are formulated in simple linear equations. The equations are simple yet powerful for the macro-level planning process. A wide range of general effectiveness trends can be examined without an exhaustive degree of trial and error or data manipulation. Response analysis can identify the critical elements impacting solution optimality. Insights gained from linear programming can then be tested by more comprehensive types of analysis such as combat simulations, which have a higher level of resolution for the specific area being analyzed.

1-5. IMPLEMENTATION. GLOFAM is implemented on a Microsoft Excel-based spreadsheet using a linear programming optimizer called Super MacVINO. (Super MacVINO also has the capability to solve mixed integer problems. The model runs on a Macintosh II in under 5 minutes. GLOFAM is very straightforward. The spreadsheet format provides a user-friendly environment. Numerical input data and the appropriate formulas (objective functions, constraints, etc.) are contained in the GLOFAM spreadsheet. Super MacVINO reads the input data, converts them into a linear programming format, and then tries to optimize the objective function.

1-6. SUMMARY

- a. GLOFAM was developed to be used as:
 - (1) A main study model for quick reaction analysis (QRA) and force planning under conditions of uncertainty.
 - (2) A screening tool prior to detailed analysis in campaign simulations.
- b. GLOFAM provides:
 - (1) Recommended force structure (combat, combat support, combat service support, and general support including TDA) for given resource constraints of given strategic objectives.
 - (2) Cost-benefit analysis.
 - (3) Insights into benefits from modernization and/or force structure (table of organization and equipment (TOE)) changes.
 - (4) Quick turnaround analysis.
- c. Figure 1-1 illustrates the GLOFAM force planning process.

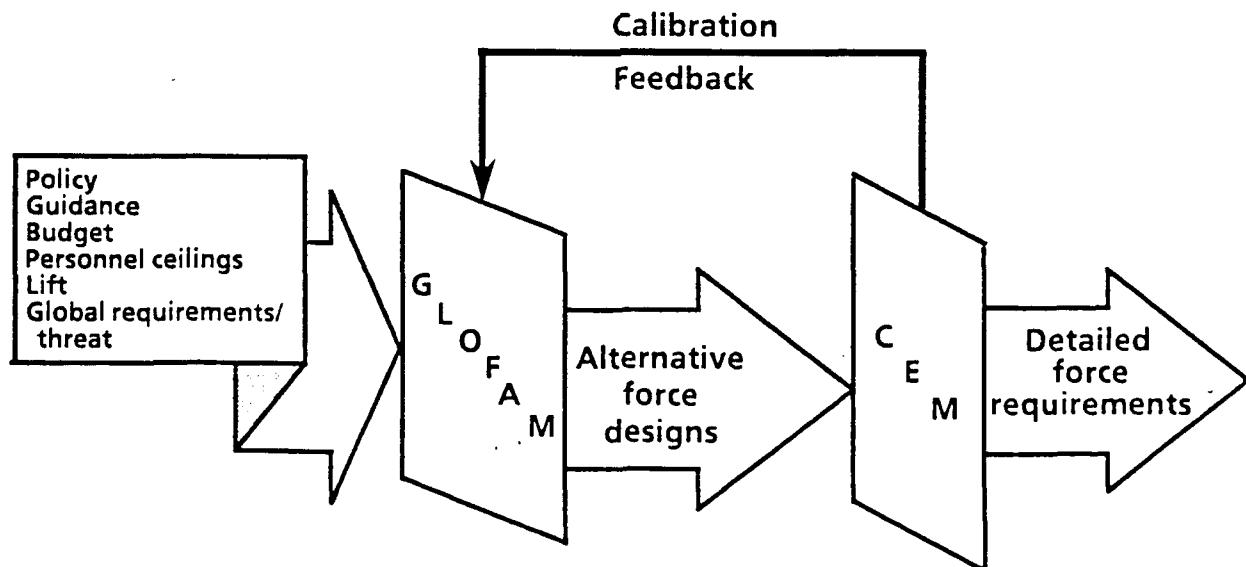


Figure 1-1. The GLOFAM Force Planning Process

CHAPTER 2

METHODOLOGY

2-1. PURPOSE. This chapter describes the methodology used in formulating the model. First, a verbal description of the model is presented, followed by a mathematical description of the linear programming formulation.

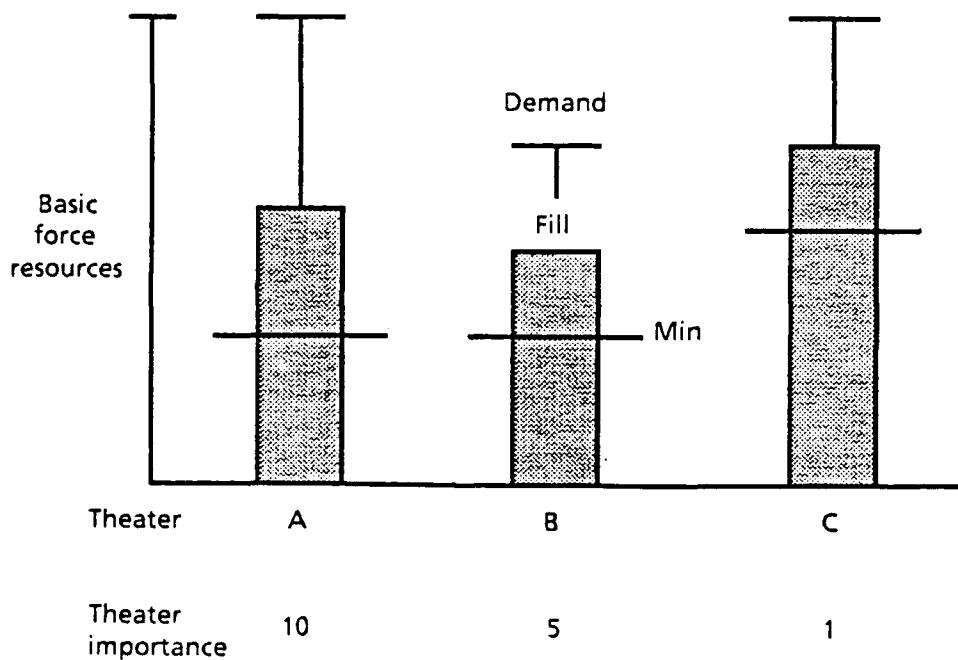
2-2. A DEMAND FUNCTION REPRESENTING THE NATIONAL SECURITY INTERESTS

a. GLOFAM designs the force which best meets global theater requirements by considering alternatives in unit type, readiness/responsiveness, deployability, and cost effectiveness. Table 2-1 summarizes model parameters/variables. No level of force structure could ever completely guarantee security, but military planners can identify forces which give a reasonable assurance of success in the theaters. These levels can be used as appropriate objectives in GLOFAM and can be correlated to the results of theater campaign simulations for increased confidence. These target levels are represented in a demand function. At the macro level, this demand function reduces national security interests in all theaters to common terms.

Table 2-1. GLOFAM Parameters

Parameter	Representation
Force Structure	
Standard requirement code (SRC) stylized into divisional increment (DI), nondivisional combat increment (NDCI), tactical support increment (TSI)	Costs Manpower
Combat power	Unit combat power potential
Component	Active/Reserve
Strategic deployability	Unit availability
Readiness	
Authorized level of organization (ALO) levels 1-3	Appropriate levels of manpower, weapons, costs
Readiness levels C1-C4	Unit availability
Stationing	Forward, prepositioned equipment, continental United States (CONUS)
Modernization	
Organizational structure	Costs, manpower
Equipment	Weapon systems
Sustainability	
Support capability	TSI

b. Filling demand in one theater may cause shortfalls to occur in other theaters because of the potential scarcity of resources (manpower, budget, combat units, and combat service support units) which satisfy demands. Some criteria must be established for allocating the resources across the demand. In GLOFAM, the demand function is filled so as to minimize the overall aggregate degree of shortfall once minimum requirements are met. Shortfalls in each theater are weighted according to their relative importance to US interests and likelihood of occurrence and summed across time periods to determine the overall weighted shortfall. This overall weighted shortfall defines risk and constitutes the objective function to be minimized in GLOFAM. This technique allows critical theaters to receive primary attention during fill without ignoring minimum requirements in the lesser theaters. This concept is illustrated in Figure 2-1.



Global demand function = Demand A + Demand B + Demand C

Weighted shortfall function = S (Demand-fill) * Theater importance

Figure 2-1. Example of Demand Satisfaction in GLOFAM

c. GLOFAM strives to fill this demand function within force level constraints. A target and a minimum force level must be established for each theater and time period. The target is the ideal force level to ensure a

successful outcome. The target equals the demand. Individual target levels cannot be exceeded in order to preclude waste of resources. The minimum is the level below which mission objectives must certainly fail to be met. The interval between these points defines the region of shortfall from the ideal level. If the target is achieved in all theaters at all times, the total risk is zero. If the model is not able to allocate forces to at least the minimum level in all cases, the result will be an infeasible solution.

2-3. FILLING DEMAND. Currently, a demand in GLOFAM is represented by the size of the force required to meet a threat. In order to define the demand, forces on both sides of a possible conflict must be evaluated in terms of their potential combat power. This can be done in many possible ways. One way to do it is to count all the major weapon systems in the force and evaluate them based on their technology or age. Another way is to simply count all the units in the force. Once this evaluation process, which quantifies the combat potential, is completed, the relative combat power (RCP) of the opposing forces can be determined and related to the force mission and objectives for the area of operations being considered. In this case, relative combat power can be expressed as a ratio of each side's combat power. The difference between the actual and target relative combat power is then used to establish the requirement for additional forces. This is the same as the procedure used in the US Army by commanders in making what is referred to as the Estimate of the Situation, upon which decisions are based as to which course of action is taken to achieve force objectives. GLOFAM designs a force that achieves the relative combat power to the greatest extent possible within each theater given the requirements in all theaters. In addition, criteria such as allocation or demand satisfaction rules may be used for theaters or requirements where defining threat force potential is not appropriate or cannot be explicitly measured.

2-4. CORRELATION TO CAMPAIGN SIMULATION RESULTS. Target force levels can be established based on the analysis of the outcomes of combat simulations, wargames, and other models to the greatest extent possible. Outcomes in which US forces were successful in accomplishing the designated theater strategic objectives are examined to determine what the RCPs were at the time intervals used in GLOFAM. These can then be used to establish target RCPs. GLOFAM thus becomes an auxiliary to the simulation models and can be used to estimate force level requirements without the detailed requirements of the higher resolution models. These results can in turn be used as the basis for future simulations. This process, which is shown in Figure 2-2, enables the fast-running linear programming model and the detailed campaign simulation to complement and enhance each other as the results of each are compared. This synergistic approach has been described as the use of "complex combat models as research tools to determine basic relations that can be presented to decisionmakers with simple, transparent, easily-understood models. The detailed combat model could be used as a device for developing confidence in the ability of the simple model to reflect the same trends as the complex one and consequently for giving credibility to the simple model. In this context the complex model serves as the "back-up" for the simple model. This approach is essentially the coordinated use of the large-scale complex operational model with a simple auxiliary model". (Reference page 114, Force-on-Force Attrition Modelling.) A simple model has the further advantage of facilitating communication with the decisionmaker.

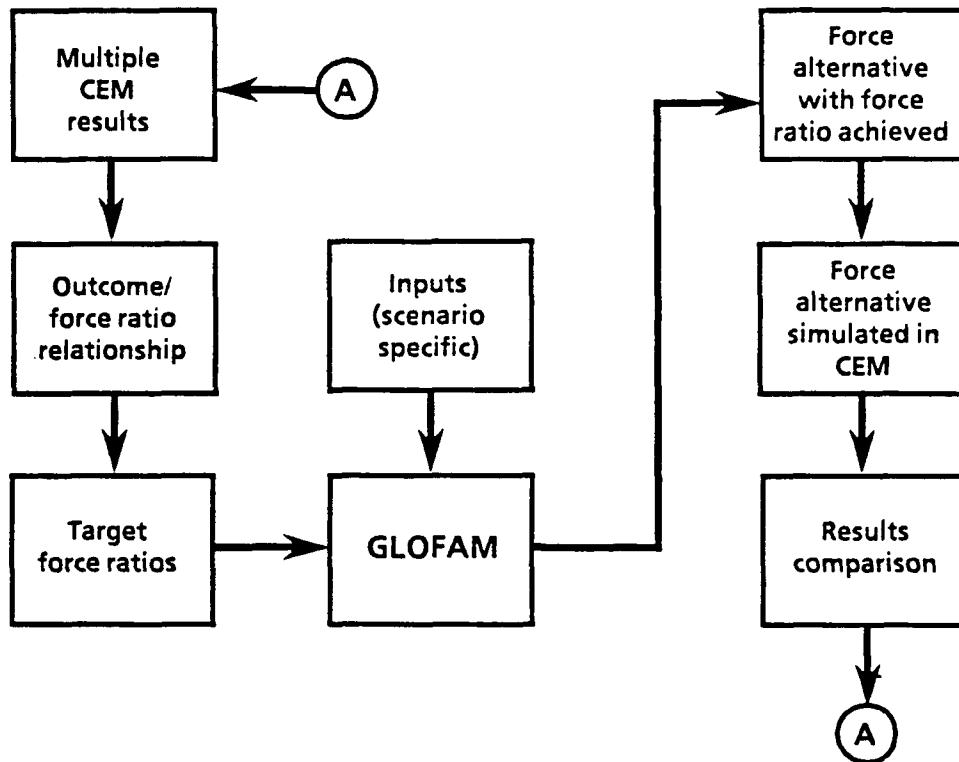


Figure 2-2. GLOFAM/Simulation Linkage

2-5. POTENTIAL COMBAT POWER. GLOFAM uses potential combat power to quantify the basic attributes of combat units. This is then used to determine relative power of the opposing forces. Whole combat units or individual weapon systems can be the basic building-blocks of force design at the operational level. Combat units consist of an aggregation of different weapon system types, other equipment, and personnel operating to achieve a common purpose. The combat potential of such an organization can be quantified through a variety of techniques such as the two described in the previous paragraph to approximate the potential combat contribution of each unit type. In GLOFAM, combat units are currently represented at the brigade level for US units and division or brigade level for all others. Examples of unit types currently evaluated are shown in Table 2-2. Other sizes and types of units, including Special Operations Forces (SOF), can be modeled as required.

Table 2-2. Combat Unit Types Represented in GLOFAM

Heavy units	Light units
Armor (tank)	Standard Infantry
Mechanized Infantry	Light Infantry
Motorized Rifle	Air Assault
Armored Cavalry	Airborne
	Motorized Infantry

2-6. THEATER MULTIPLIER. The theater multiplier takes into account the impact of such factors as terrain, combat support, and mission on potential combat power. The goal in GLOFAM is to design a force with the resources to meet the requirements of multitheater demands. The general estimates of military effectiveness outlined in the previous paragraph must be tailored to the mission, enemy, terrain, and allied troops available in each individual theater. Relative effectiveness of different unit types changes radically in different theaters. For example, an armored unit does not have the same value in a jungle guerrilla campaign as it does on the plains of Europe. For this reason, each unit type in GLOFAM has been given a multiplier to modify division effectiveness in such a way that changes in terrain and mission are modeled. The multiplier is currently represented as a single factor for each theater. For example, operations which can be represented in GLOFAM range in scale from traditional high-intensity European theaters to low-intensity guerrilla operations.

2-7. IMPACT OF AVAILABILITY/DEPLOYABILITY ON POTENTIAL COMBAT POWER. The response capability of US forces over time is a key element in force design. Therefore, relative combat power is calculated in five distinct time phases for each theater in GLOFAM. This allows a demand for forces to be generated for each of the time-periods and forces the model to consider both availability and deployability of units in designing the force. As an example, forward-deployed units count more in the risk-minimization function than units arriving later in-theater because risk must be minimized during all five time-periods. In other words, they are available earlier and contribute their combat power over a greater period of time. Another example is that an Active Component unit, although more expensive, requires less time to deploy than does a comparable Reserve Component unit and therefore has greater impact in filling the demand function. Units with forward-stationed material (prepositioned materiel configured to unit sets (POMCUS)) also gain in effectiveness due to their more rapid responsiveness.

2-8. CONSTRAINTS ON FORCE DESIGN. Force design in GLOFAM is constrained by force availability, personnel strength levels, budget, and lift constraints.

a. Force Availability. One of the functions of the GLOFAM linear program is to minimize risk within the limit of a specified maximum number of US units. This number could represent an inherited force or a policy decision constraint. Within this number of units, the model is free to select as many of a particular type as will best fill the demand. (A policy constraint, however, may be placed on the number of each type of unit.) Should it be desired to constrain force selection on the basis of end strength or cost (discussed below), the number of each unit type can be made effectively limitless as a model input. Then, either personnel or cost would define the boundaries of the number of units.

b. Personnel Strengths. Personnel strengths are assigned to each type of unit available to the model. When the model determines the force required, the sum of the personnel strengths constitutes the deployable force. Active and reserve personnel are totaled separately. An empirically-derived equation then estimates the size of the nondeployable force. The sum of the deployable and nondeployable forces is the required end strength. The personnel strength can be a model output or an input constraint. The latter condition can occur for a variety of budgetary, planning, or legislative reasons. The magnitude of the end strength is specified, and a force must be constructed which will comply with this limitation. The model can also accept end-strength as an input constraint and determine the number and types of units which will minimize risk in accordance with this specific condition.

c. Annual Costs. The annual peacetime operating and support cost of the deployable force postured by the model is calculated. This cost is the sum of the personnel cost and the operations and maintenance cost. The derivation of factors for these costs is explained in Chapter 3. The determination of cost may be required to function within a constraint. This occurs frequently when several cost plateaus are included in fiscal guidance issued to the services. It is also common for military planners to begin force development studies with a target cost in mind. In such cases, a maximum cost will be stipulated, and the model will be restricted in its force selection to a structure in consonance with the given degree of affordability. This maximum may be expressed in terms of a percentage of some reference cost level, such as a previously approved amount. The model will then minimize risk within the context of this constraint.

d. Lift Constraints. As the model structures a mix of forces, it makes its selection based on a corresponding closure time of each unit to the theater. Accordingly, the effect of forward deployment and the ability of the transportation system to deliver forces may be studied by the placement of constraints upon the amount of force which may arrive in any given time interval. This feature also offers the capability to examine the transfer of forces between theaters. In this context, it can also be used in conjunction with an eroded unit effectiveness due to attrition and/or some other cause of decreased capability associated with deployment.

2-9. LINEAR PROGRAMMING FRAMEWORK

a. The linear program (LP) is used to "fill" the demand function in an optimal manner. As indicated in the beginning of the methodology paragraph, the demand function may not be completely satisfied due to constraints. The existence of feasible alternative solutions is limited by the design constraints imposed. Infeasible solutions indicate that the minimum requirement cannot be met under a certain set of conditions. GLOFAM can currently be operated in two ways; first, risk can be minimized with or without constraints on cost and/or personnel. The formulation is as follows:

Minimize Risk (shortfall from combat power objective)

SUBJECT TO:

- 1) Resource constraints (AC/RC personnel, dollars)
- 2) Unit availability and deployability
- 3) Stationing criteria (forward-stationing)
- 4) Other policy criteria

Alternatively, cost can be minimized subject to constraints on risk, personnel, and number of units. This formulation is as follows:

Minimize Cost (dollars)

SUBJECT TO:

- 1) AC/RC personnel ceilings
- 2) Minimum combat potential goals
- 3) Force availability and deployability
- 4) Stationing criteria
- 5) Other policy criteria

b. GLOFAM can also be operated in a two-step procedure where minimizing risk is the first priority and minimizing cost is a secondary priority. The risk-minimization version is run first. Then the risk level achieved in the initial run is used as a constraint in the cost-minimization routine. This procedure allows for the investigation of alternative designs which may not meet all goals for effectiveness and cost, but which attempts to meet those goals as closely as possible. The mathematical formulation of the linear program is now presented. GLOFAM produces the time-phased force requirements for multiple theaters/demands.

2-10. MATHEMATICAL DESCRIPTION

a. Index Variables

- AC - Active Component
- RC - Reserve Component
- i - indicates theater
- j - indicates time period
- a - indicates Blue combat unit type
- e - indicates Red combat unit type
- t = total number of theaters
- p = total number of time periods

k = total number of Blue unit types
 l = total number of Red unit types

b. **Objective Function(s).** Two objective functions are shown here. Only one is active during an execution of the model. The first minimizes risk (equation (1)) and the second minimizes cost (equation (4)).

Minimizes risk (weighted shortfall)

$$(1) \quad \text{Minimize } WS = \sum_{i=1}^t \sum_{j=1}^p (D_{ij} - RCP_{ij}) * TI_i$$

WS = weighted shortfall or risk

D_{ij} = force ratio demand (or target relative combat power)

TI_i = theater importance to US interests

RCP_{ij} = actual relative combat power

in which relative combat power

$$(2) \quad RCP_{ij} = \frac{BF_{ij}}{RF_{ij}}$$

BF_{ij} = Blue combat power

RF_{ij} = Red combat power

and Blue/Red combat powers are

$$(3) \quad BF_{ij} = \sum_{a=1}^k BQ_{aij} * BC_{aij} * BMTT_{ai}$$

$$RF_{ij} = \sum_{e=1}^l RQ_{eij} * RC_{ei} * RMTT_{ei}$$

BQ_{aij} = quantity of Blue unit type

RQ_{eij} = quantity of Red unit type

BC_{aij} = Blue unit potential combat power

RC_{ei} = Red unit potential combat power

$BMTT_{ai}$ = Blue theater multiplier

$RMTT_{ei}$ = Red theater multiplier

BC_{aij} is determined by CDAY and fixed prior to model optimization.

The second objective function minimizes the annual recurring operating and support (O&S) cost of the deployable force.

$$(4) \quad \text{Minimize } AS = C_{AC} + C_{RC}$$

AS = O&S cost of deployable force
 CAC = O&S cost of AC deployable force
 CRC = O&S cost of RC deployable force

Although other objective functions are of course possible, the two presented here are presently the most important to the model.

c. Decision variables

BQ_{aij} = quantity of Blue unit type
 RQ_{ej} = quantity of Red unit type

BQ_{aij} contains both US and allied forces. At the present time, only BQ_{aij} representing US units comprise the decision variables. Allied BQ_{aij} and RQ_{ej} are not decision variables and are thus fixed for all aij and ej during execution of the model. (For the remainder of this paper, BQ_{aij} refers to US only.)

d. Constraints

Policy constraints may be placed upon the decision variables, BQ_{aij}. For example, if a unit of a certain kind is considered unavailable because of readiness restrictions, its BQ_{aij} may be set equal to zero. Also, a maximum number of forward-deployed units may be specified. Similarly, it may be desired to limit a certain type of unit to not more than a particular number.

Following-day constraint

$$(5) \quad BQ_{ai(j+1)} \geq BQ_{aij}$$

This constraint ensures that units allocated in a time period must be present in subsequent time periods.

Target ratio (demand) is the maximum acceptable relative combat power.

$$(6) \quad D_{ij} = RCP_{ij_{max}}$$

The model also requires the specification of a minimum RCP. Actual RCP therefore lies between limits.

$$(7) \quad RCP_{ij_{min}} \leq RCP_{ij} \leq RCP_{ij_{max}}$$

Lift Constraints. Lift capacity is determined by C-day. Lift constraints are optional. They limit the Blue unit type decision variables by time period according to lift capacity available. There is one lift capacity for

total US units and another for heavy US units. Lift capacity is expressed in terms of brigades.

$$(8) \quad HVb_{ij} \leq HCAP_{ij} \\ Tb_{ij} \leq TCAP_{ij}$$

$$(9) \quad Tb_{ij} = HVb_{ij} + LTb_{ij}$$

$HCAP_{ij}$ = heavy lift capacity

$TCAP_{ij}$ = total lift capacity

HVb_{ij} = total number of heavy brigades (AR,MX)

LTb_{ij} = total number of light brigades (LT,AB,AA)

Tb_{ij} = total number of brigades

Reserve availability. The BQ_{aij} for reserve units can be constrained according to when they are available relative to C-day. This is done by assigning a value of zero to their potential combat power, BC_{aij} , during early time periods when they are unavailable and their normal value during time periods when they are available.

In the two-step procedure referred to in paragraph 2-9b, WS is first minimized by using equation (1) as the objective function. This solution provides a particular value of total risk accompanied by a discrete set of RCP_{ij} . There is, of course, a corresponding configuration of units for each RCP_{ij} . In the next step cost is minimized by using equation (4) as the objective function while using equation (1) as a constraint. The constraint is effected by holding constant all RCP_{ij} found as the result of the original solution. In other words, in step two

$$(10) \quad RCP_{ij_{max}} = RCP_{ij_{min}} = RCP_{ij} \text{ (as found in step one)}$$

The result is a force configuration minimized with respect to both cost and risk. The calculation of equation (4) is normally made in the final time period of the model.

Other parameters could also function as constraints. For example, personnel normally functions as an output but could very well serve as a constraint, as will be seen in the next section. The same is true for cost. The total number of US brigades could also be constrained to a specific value.

e. Personnel. The following equations give personnel data corresponding to the Blue unit decision variables.

Total combat personnel strength

$$(11) \quad CP_{AC} = \sum_{i=1}^t \sum_{a=1}^k BQ_{\alpha P} * DP_{ACa} + NFNDI_{AC}$$

$$CP_{RC} = \sum_{i=1}^t \sum_{a=1}^k BQ_{aiP} * DP_{RCa} + NFNDI_{RC}$$

$CPAC$ = total AC combat personnel
 $CPRC$ = total RC combat personnel
 $DPAC_a$ = number of AC flag combat personnel in units of the same type, divisional and nondivisional, per unit
 $DPRC_a$ = number of RC flag combat personnel in units of the same type, divisional and nondivisional, per unit
 $NFNDI_{AC}$ = total AC nonflag nondivisional combat personnel
 $NFNDI_{RC}$ = total RC nonflag nondivisional combat personnel

Nonflag nondivisional combat increment (NFNDI) personnel

$$(12) \quad NFNDI_{AC} = \sum_{a=1}^k DP_{AC_a} * DIVFAC_a * NFNDI_{FAC_{AC}}$$

AC units

$NFNDI_{RC} =$

$$\sum_{a=1}^k DP_{RC_a} * DIVFAC_a * NFNDI_{FAC_{RC}} + \sum_{a=1}^k DP_{AC_a} * DIVFAC_a * NFNDI_{FAC_{RA}}$$

RC units *AC units*

$DIVFAC_a$ = the ratio of divisional combat personnel to all flag combat personnel. The set of values is the same for both AC and RC

$NFNDI_{FAC_{AC}}$ = the ratio of AC nonflag nondivisional combat personnel to AC divisional combat personnel

$NFNDI_{FAC_{RC}}$ = the ratio of RC nonflag nondivisional combat personnel to RC divisional combat personnel

$NFNDI_{FAC_{RA}}$ = the ratio of RC nonflag nondivisional combat personnel to AC divisional combat personnel

Tactical support increment (TSI) personnel

$$(13) \quad TSI_{AC} = TSIFAC_{AC} * CP_{AC}$$

$$TSI_{RC} = TSIFAC_{RC} * CP_{RC} + TSIFAC_{RA} * CP_{AC}$$

TSI_{AC} = total AC TSI personnel
 TSI_{RC} = total RC TSI personnel

TSI FACAC = the ratio of AC TSI personnel to AC combat personnel

TSI FACRC = the ratio of RC TSI personnel to RC combat personnel

TSI FACRA = the ratio of RC TSI personnel to AC combat personnel

Total deployable force personnel

$$(14) \quad TDP_{AC} = CP_{AC} + TSI_{AC}$$

$$TDP_{RC} = CP_{RC} + TSI_{RC}$$

TDPAC = total AC deployable force personnel

TDPRC = total RC deployable force personnel

Total end strength personnel

$$(15) \quad ES_{AC} = IFAC_{AC} * TDP_{AC}$$

$$ES_{RC} = IFAC_{RC} * TDP_{RC}$$

ESAC = total AC end strength

ESRC = total RC end strength

IFACAC = the ratio of AC end strength to AC deployable force personnel

IFACRC = the ratio of RC end strength to RC deployable force personnel

Constraints on total end strength. The following two equations are constraints on total end strength. They are optional and may be applied when appropriate.

$$(16) \quad ES_{AC} \leq LES_{AC}$$

$$ES_{RC} \leq LES_{RC}$$

LESAC = upper limit on total AC end strength

LESRC = upper limit on total RC end strength

f. Cost. Cost is the operating and support cost associated with the unit type decision variables.

Cost by type brigade

See Chapter 3 for derivation of $CBAC_a$ and $CBRC_a$.

$CBAC_a$ = O&S cost of a given type of Active brigade

$CBRC_a$ = O&S cost of a given type of Reserve brigade

Per capita cost factors

See Chapter 3 for derivation of W and X.

W = per capita O&S cost for AC
 X = per capita O&S cost for RC

Deployable force cost. The calculation is normally done in the final time period of the model.

$$AS = C_{AC} + C_{RC}$$

$$(17) \quad C_{AC} = \sum_{i=1}^t \sum_{a=1}^k BQ_{aip} * CB_{ACa} + W * (NFNDI_{AC} + TSI_{AC})$$

$$C_{RC} = \sum_{i=1}^t \sum_{a=1}^k BQ_{aip} * CB_{RCa} + X * (NFNDI_{RC} + TSI_{RC})$$

Deployable force cost constraint. Cost constraint is optional.

$$(18) \quad AS \leq LAS$$

LAS = annual spending limit for deployable force

g. Flag NDCI (FNDCI) Brigades. Answers are optimized based on combat brigades without distinction between divisional brigades and nondivisional brigades. After optimization, the two types are split out according to observation of present mix.

$$(19) \quad BQ_{ap} = \sum_{i=1}^t BQ_{aip}$$

$$(20) \quad BFNDI_{ap} = BQ_{ap} * FNDCIFAC_a$$

$$(21) \quad DI_{ap} = (BQ_{ap} * DIVFAC_a) / 3$$

$$(22) \quad DBDE_{ap} = DI_{ap} * 3$$

DI_{ap} = divisional brigades (in divs)
 $BFNDI_{ap}$ = nondivisional brigades (in bdes)
 $DBDE_{ap}$ = divisional brigades (in bdes)
 BQ_{ap} = total quantity of Blue units in last time period
 (divisional and nondivisional brigades)

FNDCI FAC_a = a factor which is the ratio of nondivisional combat brigades to all combat brigades, divisional and non-divisional. The set of values is the same for both AC and RC.

2-11. SPREADSHEET FORMAT

a. Figure 2-3 is a brief representation of the format used in GLOFAM. Theaters are aligned horizontally. There presently is a nine-theater capacity. Theaters may be activated in isolation or in combination. Within each theater there are five columns representing time periods. These five time periods are presently D-day, D+5, D+15, D+30, and D+45. Unit types are listed vertically, each with its potential combat power. For each type unit, each theater has its multiplier. The array of cells in the body of the spreadsheet represents the decision variables. These are determined in the solution given by the model. Each of these cells will contain a number which is the number of units of a particular type at a specific time in a given theater allocated by the model in accordance with the objective function and its constraints.

b. The manpower and cost section of Figure 2-3 acts upon the sum of the D+45 columns of the theaters. It produces manpower and cost for each type unit over all theaters. The vertical sum of each of the two columns is the manpower and cost of the combat force. To this is added the manpower and cost of the NFNDCI and TSI. The result is the manpower and cost of the deployable force. The addition of manpower for the nondeployable force, or infrastructure, provides an estimate of end strength. It distinguishes between AC and RC.

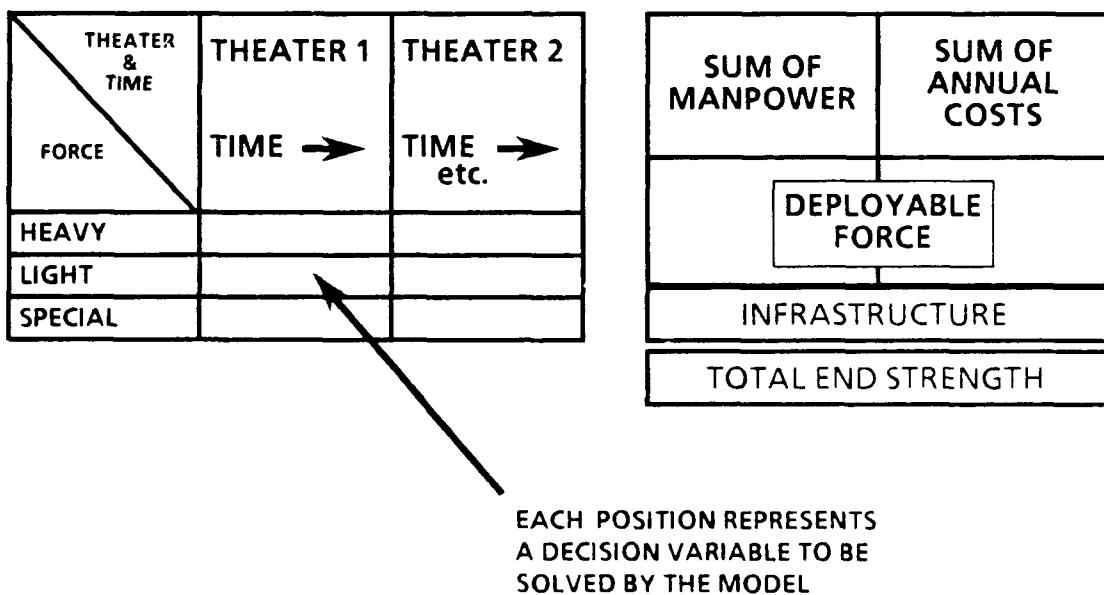


Figure 2-3. Representation of the Global Force Allocation Model

2-12. VERIFICATION AND VALIDATION. Models under the control of the US Army are required by policy to be verified and validated in order to ensure correctness and full endorsement of results. According to a briefing prepared by John A. Riente, HQDA ODCSOPS, Office of the Technical Advisor; verification is the process of determining that a model accurately reflects the developer's conceptual description and specifications; validation is the process of determining that a model accurately represents the intended real-world entity. Verification and validation have been conducted on GLOFAM during development and will continue throughout the model's operational lifetime. Figure 2-4 illustrates this process.

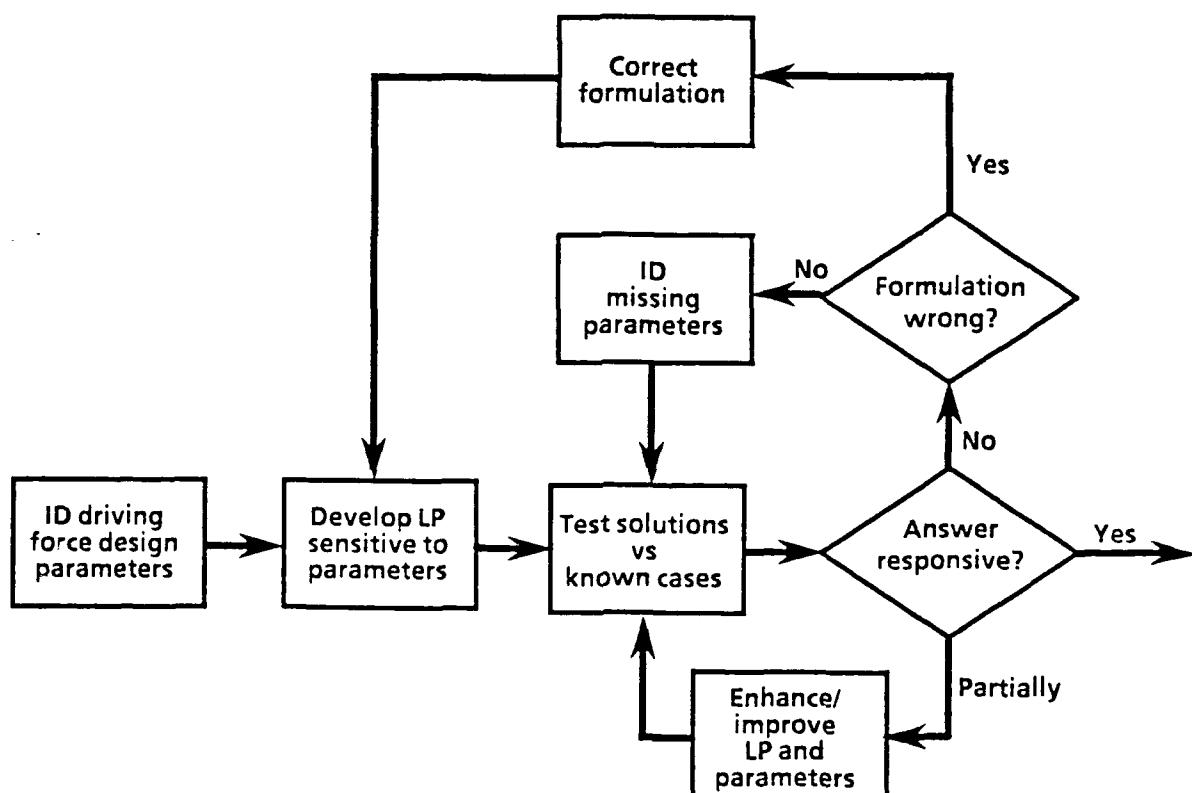


Figure 2-4. GLOFAM Development, Validation, and Verification Process

2-13. VERIFICATION

a. Calculations. Each time modifications are made to GLOFAM, computation of parameters/outputs is checked by hand. The linear programming formulation, which is coded in spreadsheet format, is also carefully checked against the intended mathematical formulation. A certain amount of care is necessary in order to maintain the integrity of the spreadsheet.

- Each cell of the spreadsheet can represent a number or an equation.
- Decision variables must be distinguished from fixed parameters.

- Constraints must be distinguished from computational equations.
- One equation must be identified as the objective function.
- None of the decision variables may be allowed to be a nonlinear term in an equation.

b. Operation. Execution of the model during optimization is also checked during verification procedures. Running linear programming algorithms on a computer can cause suboptimality and infeasibility problems. One type of problem occurs because of the limitations of computer precision and is caused by improperly scaled parameters. In Linear Programming in Single and Multiple Objective Systems, Ignizio states that scaling errors can become more serious as roundoff error causes inaccuracies to accumulate over solution search iterations.

c. Optimality. GLOFAM typically requires many iterations to reach optimality. Solutions which were feasible but suboptimal were obtained with MacVINO during the early phases of GLOFAM development. Starting with a prior basis (feasible solution set) as an initial basis often exacerbated the problem. This condition was subtle but was eventually detected. Some decision variables entered the solution at the expense of ones possessing a higher payoff value. Although MacVINO did not (and cannot) detect the condition of suboptimality, MacVINO did alert the developers to the possibility of scaling errors. The scaling errors were traced as the cause of suboptimality. The problem was solved by rescaling pairs of parameters.

2-14. VALIDATION

a. Quality Assurance. CAA products are carefully audited by an in-house top level staff and technical experts. In April 1991, the GLOFAM methodology was subjected to an Analysis Review Board (ARB) and approved for Agency use.

b. Selection of Parameters. The force design parameters, already given in Table 2-1, are based on resident expertise (corporate knowledge) developed over many years responding to DAMO-SSW requests for theater-level force design analysis. The parameters identified as being highly significant in GLOFAM were established and documented during many years of careful research conducted under the Mid-Range Force Study (MRFS). The resulting parameters represent the culmination of this research, updated to reflect current changes in the world situation/US Army requirements.

c. As explained in paragraph 2-4, some of the parameters used in GLOFAM are calibrated to the results of theater campaign simulations so that the GLOFAM results can be used to estimate the results that would be obtained using a simulation model. Chapter 4 provides an illustrative analysis which presents a typical solution being obtained using GLOFAM.

CHAPTER 3

GLOFAM COSTING METHODOLOGY

3-1. INTRODUCTION

a. This chapter discusses the process used in the computation of the operations and maintenance (O&M) and military personnel costs of the Active Army and Reserve Components. Costs were computed for different types of organizations and applied to the resource allocation output levels derived from the model. The parameters and variables used are based on data inputs from the Force Accounting System (FAS) and Total Army Force Cost System (TAFCS). The explanation which follows can be facilitated by reference to Figure 3-1.

3-2. COST ASSUMPTIONS. The assumptions used in developing costs for this analysis are as follows:

a. Data obtained from sources such as the FAS, TAFCS, and the Cost and Economic Analysis Center (CEAC) and their associated secondary files are accurate and represent the best available data as of January 1991.

b. The personnel levels are computed at ALO-1.

c. The equipment readiness levels were calculated at C-3.

d. The ratio of Reserve Component nonoperational tempo (non-optempo) costs to Active Component non-optempo costs is the same as the ratio of RC optempo costs to AC optempo costs (27 percent). (Operational tempo is the utilization rate of a piece of equipment with respect to time.)

3-3. O&M COSTS. The subprograms of O&M costs are shown in Table 3-1. A portion of P2 costs is calculated on an optempo basis. The remaining portion of P2 costs, as well as all other costs, are calculated on a non-optempo basis and use per capita worldwide average factors. These factors are shown in Table 3-2. The non-optempo portion of P2 costs and a portion of P8T costs are each attributable to the sum of Base Operations (BO) cost and the Real Property Maintenance Account (RPMA). These BO and RPMA costs have been combined and appear as a sum on the first line of Table 3-2. What remains of P8T costs is shown on the fifth line of Table 3-2. The per capita costs were provided by CEAC. The derivation of P2 optempo costs is described in the paragraphs which follow.

a. FAS Extract

(1) Cost-All Data Base File (DBF)

(a) The first step in the process was to extract selected information from the FAS with 1991 unit activation dates. Identification of divisions was made by troop program sequence number, Army (TPSNA). The TPSNA includes the following categories: (1) Active Army, (2) Reserve, and (3) roundout

units (2/3 Active Army and 1/3 Reserve). All SRCs, which were identified by unit identification code (UIC) within each TPSNA, were extracted.

(b) The Cost-All DBF is organized based on a TPSNA/SRC/UIC relationship with corresponding personnel authorizations for both active and reserve units. A list of TPSNAs was defined by the study team to provide the nomenclature for each organization. Codes were assigned to represent each of the unit types--A for Active Army, R for Reserve, and AR for roundout units.

(c) TPSNAs are five-digit codes which group units by mission, type, and size. The classes of organizations defined by TPSNAs for which costs were derived include the following: cavalry divisions, infantry divisions, infantry divisions (light), infantry divisions (mechanized), airborne divisions, infantry brigades, infantry brigades (mechanized), and armored cavalry regiments.

Table 3-1. Definition of O&M Budget Subprograms

1. P2 (Land Forces) - Mission: The operation and maintenance of division forces, special mission forces, and theater support forces.
2. P7S (Supply) - Mission: The operation of supply depots and centrally managed supply management activities.
3. P7T (Transportation) - Mission: The movement of materiel from manufacturers, Army depots, and unit locations to Army units around the world, including traffic management and port terminal operations.
4. P7M (Depot Maintenance) - Mission: Depot level overhaul, repair, and modification/conversion of unserviceable but repairable materiel for issue to troops in the field.
5. P8T (Training) - Mission: The operation of the Army school system, training centers, and other activities to support initial entry, skill, and functional training, and professional education of military personnel.
6. P8M (Medical) - Mission: The provision of health services for eligible personnel and medical training for health care providers.
7. P8O (Other Personnel Activities) - Mission: The operation of the Army's accession program (recruiting, advertising, and examining), reception stations, certain education programs, and other personnel-related activities.

Table 3-2. O&M per Capita Cost Factors, Non-Optempo, Active Army (worldwide) (\$FY 91)

Category	Per capita cost
Base Operations and RPMA	\$2,975
P7S Supply	\$126
P7T Transportation	\$2,433
P7M Depot Maintenance	\$906
P8T Training	\$395
P8M Medical	\$1,014
P8O Other	\$105
Total	\$7,954

(d) Personnel authorizations were aggregated by like-type unit, summed within each aggregate, and divided by the number of brigades contained in each respective aggregate. The result is the average authorized personnel of a brigade of a particular type in the US Army. These values were entered in the model for the units. They are shown in Table 4-3, Chapter 4.

b. TAFCS Extracts

(1) The following data files represent some of the data bases that comprise the TAFCS which were used for the computation of the O&M costs: Part-Gas DBF, Optempo DBF, Roptempo DBF. In these files, the data originates from the input and factors that are part of the Operating and Support Management Information System (OSMIS).

(a) Part-Gas DBF. This file provides the Armywide cost factors by line item number (LIN) for repairs, spares, and POL (petroleum, oils, and lubricants). A total of 119 LINs is represented. Each LIN has a cost factor expressed as dollars per hour, mile, or total system.

(b) Optempo DBF. This file provides quantity and utilization rate by SRC and LIN for major items of equipment of Active Army units. Quantity is based on the ALO selected. Utilization rates are given in terms of hours or miles per year and is based on C-rating (readiness level). Several systems did not have values assigned to this unit of measure data field. In this instance, these systems were broken down by total system cost. Included in this group were LINs such as J82250, PATRIOT and T69778, TOW CHAPARRAL. These did not have any C-rating values and were computed by total system costs. Factors based on historical data files can be used to adjust the C-ratings.

(c) Roptempo DBF. This file is identical to the Optempo file except that it is for Reserve units. The optempo rates for the Reserve were generally about 27 percent of those for the Active Army and are the basis for assumption d of paragraph 3-2.

(2) The Optempo/Roptempo files contain LINs which represent equipment purchased under the following appropriations: aircraft (ACFT), missiles (MSLS), other procurement, Army (OPA)1, OPA2, OPA3, and weapons and tracked combat vehicles (WTCV). There is a total of 87 LINs in these files. These LINs also exist in the Part-Gas file. Only 85 percent of an SRC's equipment is published on a LIN basis. A multiplier of 1/.85 or 1.18 was therefore used on the data as an adjustment to account for the unpublished optempo rates.

(3) The Part-Gas, Optempo, and Roptempo data files were then manipulated, restructured, and indexed. Based upon the LIN linkage between the Optempo (or Roptempo) file and the Part-Gas file, a product was computed by multiplying together an equipment's quantity, utilization rate, and repair/spare/POL cost factors. The output was an array of costs in the form of an SRC/LIN file.

c. The TPSNA/SRC-structured output of the Cost-A11 DBF was merged, on the basis of SRC linkage, with the SRC/LIN-structured output of the three TAFCS-extracted files to define an optempo-based portion of OMA costs expressed in terms of TPSNA/SRC.

(1) The SRCs on the FAS file had to be edited manually so that a character-to-character match could be done. Several of the SRCs' last two digits had to be changed to reflect a base SRC while keeping the title of the unit the same.

(2) For example, SRC 01217L018, Command Aviation Company (UH-1), which is annotated as a modification table of organization and equipment (MTOE) on the FAS, was changed to a similar SRC, 01217L000, as annotated on the Optempo file. Similarly, SRC 01302L205, Headquarters and Headquarters Company, Division Aviation Brigade, was changed to 01302L200. The eighth and ninth character positions on the SRC refer to the intermediate table of organization and equipment (ITOE) number and reflect an MTOE unit. For purposes of this analysis, all of the nonmatches were converted to base TOE values. The TOEs on the Optempo DBF and Part-Gas DBF are based on the base TOE as developed by US Army Training and Doctrine Command (TRADOC).

d. Non-optempo cost factors were provided by CEAC on a per capita basis, worldwide, and inflated to fiscal year (FY) 91 dollars. The sum of non-optempo cost factors was \$7,954 for an Active Army unit, \$4,599 for a roundout unit, and \$2,147 for a Reserve unit.

e. Non-Optempo cost for each TPSNA/SRC combination is the product of the aggregate authorized personnel level from the Cost-A11 DBF and the per capita factor. The TPSNA was written out to give a TPSNA/SRC cost record. The cost reflects an ALO-1 personnel level, or 100 percent of authorized strength.

f. Total O&M per SRC can then be calculated by means of the following format:

Total O&M per SRC = op tempo cost + personnel per unit multiplied by the sum of the per capita factors

g. When all the SRCs within a TPSNA are summed, the final output is the O&M cost for each TPSNA.

3-4. PERSONNEL COSTS

a. Personnel costs were computed by summing up the base pay (composite standard rate) and special incentive pay for each SRC in CONUS (outside continental United States (OCONUS) values could have been used; they are approximately the same as CONUS values) at the ALO-1 level.

b. The files which provided the military pay information is the SRCPAY DBF file (Active Army units) and RSRCPAY DBF (the Reserve Components). These files are a part of the TAFC. It provides a listing of all SRCs with personnel costs from the Master TOE file.

c. The SRCs were matched to the modified Cost-All DBF and summed by SRC. From this point, all costs were rolled up by TPSNA. Reserve Component personnel costs were observed to be approximately 15 percent of those of similar Active Component units.

d. The personnel cost per unit may be slightly inaccurate due to comparing base TOE values with MTOE values. The base SRCPAY DBF and RSRCPAY DBF were developed from base TOEs. When a match is made on TPSNA/SRC, it implies that a UIC is used which is an MTOE. The majority of the MTOEs, however, do have comparable aggregate personnel levels.

3-5. O&S COSTS

a. The general methodology explained in the preceding paragraphs is summarized in Figure 3-1. The personnel costs and the O&M costs are then summed to arrive at the O&S costs.

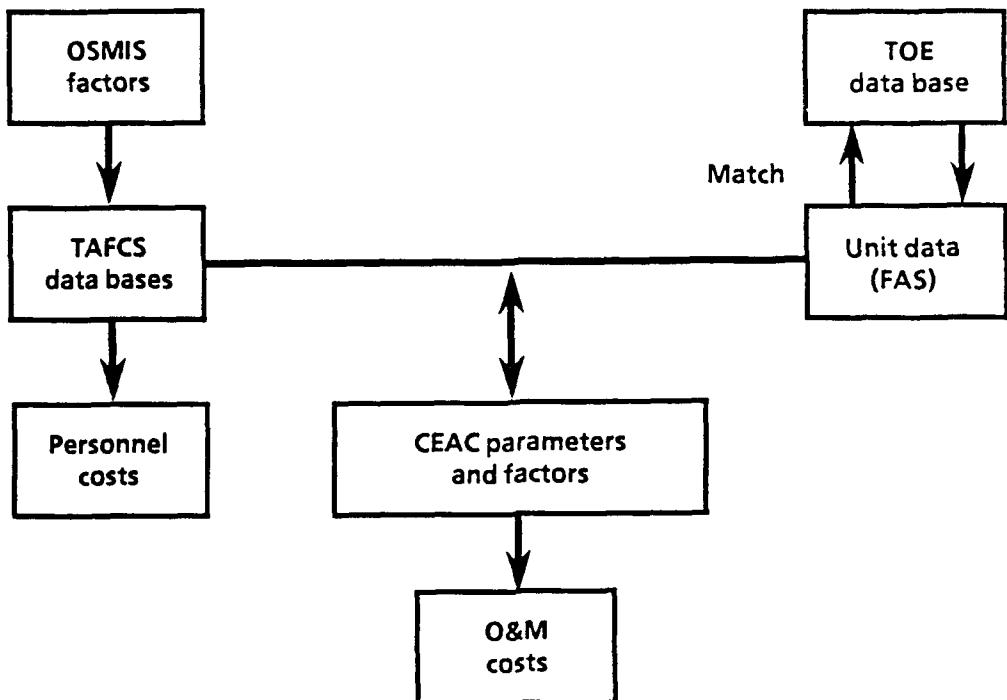


Figure 3-1. Cost Methodology

b. The O&M costs by TPSNA are added to the personnel costs by TPSNA to arrive at the O&S cost by TPSNA. Costs are then aggregated by like-type unit, summed within each aggregate, and divided by the number of brigades encompassed. The result is the average annual O&S cost of a brigade of a particular type in the US Army.

c. Since the model calculates the NFNDI and TSI in terms of numbers of individuals rather than units, per capita factors must be employed in computing their cost. To estimate this value, the cost of all TPSNAs was summed and divided by their total personnel strength as indicated by the Cost-All DBF. The resulting O&S per capita was \$42,485 for the active force and \$8,590 for the reserve force.

d. The O&S cost per capita value for the reserve is understated due to the amount of active force costs incurred in their direct support. The difficulty in identifying these costs has thus far deferred the quantification of an adjustment factor. An alternative approach to an estimation of reserve O&S per capita cost can be made by summing OMNG (Operations and Maintenance, National Guard) and NGPA (National Guard Personnel, Army) and dividing by Congressionally-authorized National Guard end strength converted to average strength. For FY 91, the respective figures are \$2.024 billion;

\$3.466 billion; 457,300; and 447,800. The resultant reserve O&S per capita factor is \$12,263. An adjustment factor would therefore be \$12,263/\$8,590, or 1.42.

e. In summary,

(1) Average O&S cost of a brigade of a particular type for the active force was calculated as in paragraph 3-5b.

(2) Average O&S cost of a brigade of a particular type for the reserve force was calculated as in paragraph 3-5b and multiplied by the adjustment factor of paragraph 3-5d.

(3) O&S per capita cost for the NFNDCI and TSI of the active force is \$42,485 from paragraph 3-5c.

(4) O&S per capita cost for the NFNDCI and TSI of the reserve force is \$12,263 from paragraph 3-5d.

These values were entered in the model and are shown in Table 4-3, Chapter 4.

CHAPTER 4

ILLUSTRATIVE ANALYSIS

Section I. GENERAL

4-1. PURPOSE. This chapter presents an illustrative analysis conducted using GLOFAM for four generic/typical theaters of operation using varying scenario conditions. All data contained in the analysis, while closely resembling real-world scenarios, are unclassified. The purpose of this analysis is to demonstrate how and why GLOFAM allocates forces, and what outputs are available from the model. For each paragraph (inputs, constraints, outputs), information applicable to all theaters is presented in a general discussion. Theater-specific information is presented in the analysis presentation for the theater concerned. The results for each theater are independent of each other.

4-2. ANALYSES OBJECTIVES. The objective of each of the four theater analyses presented was to minimize risk, as measured by the underachievement of a target RCP for each of the five time periods including and after the postulated D-day (D-day, D+5, D+15, D+30, D+45). For a given threat, the denominator of the friendly/enemy RCP used requires the model to allocate, or determine, the US force required to meet the target RCP. Underachievement is possible due to sanctioning, deployment, and readiness constraints imposed on US forces.

Section II. INPUTS

4-3. UNIT COMBAT POWER CONTRIBUTIONS

a. Tables 4-1 and 4-2 provide the unit combat power contributions used in the analysis for each type unit considered. The sum of these values for friendly and threat forces is used to determine the actual RCP present in each theater for each time period. The actual contribution of each type unit can be modified by a theater-specific factor, or combat multiplier, as explained below.

b. Combat power contributions were derived by first determining the quantities of certain designated weapon systems in each unit, adjusting for the technologies of the systems, and then normalizing all contributions relative to the base value of 1 for a modernized US armored division. For example, all tanks have a combat potential of 1. A US M1A1 tank, which represents state-of-the-art technology, has a technology multiplier of 1, giving it a combat power contribution of 1. A US M60A1 tank, which represents 1960s technology, has a technology multiplier of only .25, giving it a combat power contribution of only .25. The sum of all weapons' contributions within a unit divided by the potential for a US armor division equals the unit's normalized combat power contribution.

c. As an example the combat power of a modernized and unmodernized US armor brigade was calculated as follows:

(1) US modernized armor division was selected to have the base value of 1, to which all other units would be compared.

(2) The following items of equipment were selected as contributing to the unit combat power:

- Tanks
- APCs
- Attack helicopters
- Artillery pieces

(3) Technology coefficients were assigned as follows:

● Current technology	1.0
● 1980 technology	.75
● 1970 technology	.50
● 1960 technology	.25
● 1950 technology	00

(4) The modernized armor division combat power calculation:

Weapon	Quantity	Technology	Contribution
M1A1	348	1.0	348
IFV/CFV	316	.75	237
ITV	48	.50	24
M113	283	.25	70.25
MLRS	9	1.0	9
155mm How	72	1.0	72
AH-64	36	1.0	36
AH-1S	8	.75	6
Total			802.75

This value, normalized to 1, became the base value against which all other values are compared. Since a division contains three brigades, this combat power was equally divided among them to give each modernized armor brigade a combat power of $.33 \times 802.75 = 264.9$

(5) The unmodernized armor division combat power calculation:

Weapon	Quantity	Technology	Contribution
M1	348	.75	261
CFV	76	.75	57
ITV	92	.50	46
M113	493	.25	123.25
155mm How	72	1.0	72
AH-1S	30	.75	22.5
Total			581.7

The unmodernized armor brigade contribution is $(581.75/802.75)(.33) = .23$.

d. All other unit combat powers were calculated in a similar manner. The numbers and values shown here represent one alternative which is both reasonable and straightforward. Since the concept, not the exact numbers, is the purpose of this report no attempt will be made here to justify these particular contributions. Obviously, other schemes and methods are available and could be considered. The important point is that whatever method is used should possess the attributes of simplicity and reasonableness.

Table 4-1. Non-US Unit Potential Combat Power

Allied		Threat	
Type unit	Value	Type unit	Value
NATO heavy division	.92	USSR type tank division	.96
Notional MRC-A bde	.08	USSR type MRD	.86
Notional MRC-A hvy div	.26	MRC-A type 1 hvy div	.75
Notional MRC-A inf div	.18	MRC-A type 2 hvy div	.47
Notional MRC-B inf div	.09	MRC-A Inf div	.14
LRC light div	.16	Notional MRC-B inf div	.12
		Notional LRC light div	.16

Note: MRC=Major Regional Contingency; LRC=Lesser Regional Contingency. Both terms are from Joint Chiefs of Staff (JCS) Scenarios for the 90s.

Table 4-2. US Unit Potential Combat Power

Unit	Combat power
Modernized armor bde	.33
Modernized mech inf bde	.32
Air assault bde	.12
Airborne bde	.08
Unmodernized armor bde	.23
Unmodernized mech inf bde	.22
Light inf bde	.05
Standard inf bde	.17

4-4. THEATER IMPORTANCE. Each theater is assigned a value for its importance to the national security. This value appears in the risk-minimization version of the objective function as a coefficient to the shortfall in relative combat power. These values are subjective, and it is,

of course, only the value of one relative to another that is of consequence. In this analysis, the values used for AFCENT, MRC-W, MRC-E, and LRC were, respectively, 10, 2, 3, and 3.

4-5. THEATER MULTIPLIER

a. A theater-specific value by which the combat power contribution of each type unit is multiplied was developed to account for variations in capabilities with respect to the following factors:

- (1) Mission.
- (2) Nature of threat forces.
- (3) Terrain in which unit will operate and fight
- (4) Training for that area of operation.
- (5) Close air and other support available to forces.
- (6) Forward-stationing.
- (7) POMCUS.

b. Values for these factors are presented with the analysis for each theater in Section IV. These values are representative of reasonable and appropriate values which could be used. They represent the quantified military judgment of the analysts involved in this study. A number of factors were considered in deriving them. As an example, the multiplier of 1.5 for US forward-stationed heavy brigades in AFCENT was derived as follows:

- (1) An increase of .25 results from the contribution of US close air support (CAS) to the effectiveness of US ground forces. This can be quantified through analysis of the contribution of CAS in campaign simulations using CEM or other models.
- (2) An increase of .10 is from a determination of the non-flag non-divisional combat increment (NFNDCI) available to the units. This can be quantified through determination of weapon systems in the NFNDCI component.
- (3) An increase of .10 results from the tactical support increment (TSI) units available. This can be quantified through an analysis of the doctrinal support required compared with that required for both threat and friendly forces.
- (4) An increase of .05 results from a determination of the units' readiness, training, and familiarity with their mission, enemy, and the terrain on which they will fight.

Adding all of these increases results in a .5 increase in combat power over the base value for US forward-stationed heavy brigades.

4-6. WARNING TIME. This input determines the relationship between the time US forces begin deployment (C-day) and the time hostilities begin (D-day).

4-7. THREAT AND ALLIED FORCES

a. Allied forces: indicates number and type of friendly forces by time period whose combat power contributes to the friendly/threat RCP.

b. Threat forces: indicates the number and type of enemy forces by time period whose combat power contributes to the friendly/enemy RCP.

4-8. US UNIT RESOURCE DATA. Table 4-3 provides the personnel and cost factors used for each type of US unit. Also shown are the per capita costs used for the NFNDCI and TSI for both the AC and the RC. Cost factors represent peacetime annual recurring O&S costs. Chapter 3 provides the derivation of these factors.

Table 4-3. US Unit Personnel and Cost Factors

Type unit	Personnel	Unit cost (\$millions)
AC heavy brigade (fwd)	4,788	225.50
AC heavy brigade (POMCUS)	4,788	192.78
AC heavy brigade	4,788	191.40
RC heavy brigade	4,788	60.29
AC air assault brigade	5,200	238.29
AC airborne brigade	4,358	176.58
AC light infantry brigade (POMCUS)	3,659	152.92
AC light infantry brigade	3,659	151.54
RC light infantry brigade	3,659	53.80
AC per capita cost factor		\$42,485.00
RC per capita cost factor		\$12,263.00

4-9. TACTICAL SUPPORT INCREMENT (TSI) FACTOR

a. This factor represents the number of nondivisional support personnel required to support the divisional and nondivisional combat forces. It is derived empirically from a breakout of current US force structure and assumes the current ratio remains relatively constant and stable for all theaters. (Theater-specific values will be established in follow-on study efforts using Force Analysis Simulation of Theater Administrative and Logistic Support (FASTALS) Model outputs). Table 4-4 lists these factors.

Table 4-4. TSI Factors

Factor	Value
Total force	.6438
AC unit support	.4209 from AC, .2229 from RC
RC unit support	.6438 from RC

b. For example, for every 100 members of an AC division and its nondivisional combat units, approximately 64 nondivisional support unit personnel are required. As an Armywide average, 42 of these personnel come from the AC and 22 come from the RC. The support for RC divisions and its nondivisional combat slice of units comes entirely from the RC. Overall, therefore, 35 percent (.2229/(.4209 + .2229)) of the nondivisional support for AC divisions and their nondivisional combat slice comes from the RC.

4-10. FLAG NONDIVISIONAL COMBAT INCREMENT (FNDCI) FACTORS. FNDCI represent armored cavalry regiments (ACRs) and separate maneuver brigades (usually mechanized infantry). FNDCI become part of the solution through the use of allocation rules in a postprocessor routine. As an example, the current allocation in the model is one ACR and one separate mechanized infantry brigade per four heavy divisions. The linear program produces a result in terms of the total number of heavy brigades required. The postprocessing routine converts this to the appropriate mix of heavy divisions and FNDCI ACRs and separate mechanized infantry brigades.

4-11. NONFLAG NONDIVISIONAL COMBAT INCREMENT (NFNDCI) FACTORS

a. These factors represent the number of nondivisional combat personnel excluding those assigned to separate maneuver brigades and armored cavalry regiments required to support each person in the divisional units. All other nondivisional combat personnel (artillery, attack helicopters, combat engineers, etc.) are included in determining these factors. Table 4-5 gives these factors.

Table 4-5. NFNDCI Factors

Factor	Value
Total force	.3949
AC division support	.2444 from AC, .1505 from RC
RC division support	.3949 from RC

b. For example, for every 100 members of an AC division, approximately 39 are required as nondivisional combat support personnel. As an Armywide average, 24 of these personnel are in the AC and 15 are in the RC. Nondivisional combat personnel for RC divisions are provided entirely from RC personnel. Overall, therefore, 38 percent of NFNDCI personnel for AC divisions comes from the RC.

4-12. INFRASTRUCTURE FACTORS

a. The deployable force has been defined in terms of the three components which are used in the notional planning concept of the division force equivalent (DFE). (Reference page 10-22, Army Command and Management: Theory and Practice, 1989 - 1990.) These three components are the DI, NDCI, and TSI. In addition, GLOFAM divides the NDCI into the FNDCI and the NFNDCI. The decision cells in GLOFAM solve for the combat units, which are the sum of the DI and the FNDCI. When the model adds the NFNDCI and TSI to the combat units, the result is termed the deployable force. The NFNDCI and the TSI are predominantly, respectively, the combat support and combat service support forces. Note, however, as shown in equation (11) of paragraph 2-10e, only the NFNDCI and not the TSI is included in the definition of combat personnel.

b. Given the deployable force, a factor is needed to translate this number into an estimate of the end strength. This is the infrastructure factor; and it is designed to account for those elements of the US Army which are not included in the definition of the deployable force. Most of these elements can be accounted for by considering the categories of special theater forces (STF), general support forces (GSF), and Trainees, Transients, Holdees, and Students (TTHS). STF includes such units as theater defense brigades, Special Forces groups, and Ranger units. GSF consists primarily of those support units whose organizational structure is prescribed by a table of distribution and allowances (TDA) rather than a modification table of organization and equipment (MTOE).

c. The period 1987 to 1991 was examined relative to values of ratio of end strength to deployable force. The average ratio for the active force was 1.8278 and the average ratio for the reserve force was 1.2990. These are the values of the infrastructure factors and were entered in the model.

Section III. CONSTRAINTS

4-13. GENERAL. This section provides a verbal description of the constraints used in the analyses. The mathematical form of these constraints was presented in Chapter 2. The constraints are briefly covered, and the maximum and/or minimum values used in these analyses are shown. Theater-specific values are shown with the analysis for that theater.

a. Maximum US Forward-stationed and POMCUS Units. These constraints limit the maximum number of US units which may be forward-stationed or have prepositioned equipment in theater.

b. Maximum Number of US Units. This constraint enforces policy goals for the number of US AC and RC brigades allowed for the five time periods. For these analyses, these constraints were not active.

c. Maximum Number of US Units in Theater by Time Period. This constraint serves to limit the number of US units to that number which could actually deploy to the theater considered based on unit availability and lift assets available. Constraints are broken out for heavy, light, AC, and RC units.

d. Minimum RCP by Time Period. This constraint enforces a policy goal of a minimum RCP in each theater to ensure that all theaters are addressed before the model tries to maximize any one theater. This serves as a force floor objective when minimizing cost.

e. Maximum Cost. This constraint serves to enforce budgetary constraints when the model objective function is trying to minimize risk. Put another way, this means maximizing force levels when the threat is constant or fixed. This constraint was not in effect for this analysis.

f. Maximum Personnel. This constraint enforces manpower ceilings for the AC and RC when the model objective function is minimizing risk. A separate constraint exists for AC and RC personnel. These constraints were not active for this analysis.

g. Maximum RCP. This enforces a cap on force levels in accordance with theater objectives and national strategy and policy.

Section IV. ANALYSIS RESULTS

4-14. OVERVIEW. The results of the analysis for each of the four theaters considered is presented here. Again it is emphasized that the numbers presented are for illustrative purposes only and do NOT represent actual projected force levels for any of the types of theaters and scenarios considered.

4-15. NATO CENTRAL REGION - AFCENT

a. Analysis objective--minimize risk by achieving a friendly-to-enemy RCP of 0.6:1 as early as possible. Target RCPs are established based on what were considered successful defensive campaign simulations done using CEM. The RCPs used here are NOT the exact RCPs determined but were deemed reasonable for this unclassified analysis.

b. This, and all following theater analyses, was conducted in two phases. First, the model was run with the objective of minimizing risk subject to policy and lift constraints. This run determined if the target RCPs could be achieved and, if not, what was the best that could be had. In the second phase, the achieved RCPs were used as constraints with the objective function set to minimize cost. This determined the least cost force which could meet achievable RCPs.

c. The following are the inputs relating to the analysis.

- (1) D-day = C-day + 45 days.
RC availability = C-day + 60

(2) Unit theater multipliers:

Allied hvy div	1.00
US hvy bde (fwd)	1.50
US hvy bde	1.40
US air assault bde	1.25
US airborne bde	1.25
US light inf bde	1.25
US std inf bde	1.25
Threat div	1.00

(3) Friendly forces by time period:

	D-day	D+5	D+15	D+30	D+45
Hvy div	15	15	15	15	15

(4) Threat forces by time period:

	D-day	D+5	D+15	D+30	D+45
Tank Div	30	40	45	50	65
MRD	10	10	10	10	15

d. The following are the constraints used in the analysis:

(1) Max US forward-stationed bdes: 6

(2) Max US bdes with prepositioned equipment: 6

(3) Max US bdes by time period (based on lift assets, unit availability, and deployment time):

	D-day	D+5	D+15	D+30	D+45
Hvy bdes	18	20	20	20	20
Total bdes	25	27	27	33	41
RC bdes	00	00	00	33	41
AA bdes	3	3	3	3	3
AB bdes	3	3	3	3	3
Lt inf bdes	6	6	6	6	6

e. Based on these inputs and constraints, the following solution was obtained:

	D-day	D+5	D+15	D+30	D+45
Fwd hvy bde	6	6	6	6	6
POMUS hvy bde	6	6	6	6	6
Reinf AC hvy bde	6	8	8	8	8
Reinf RC hvy bde	0	0	0	1	9
Reinf AC AA bde	3	3	3	3	3
Reinf AC AB bde	3	3	3	3	3
Reinf AC ID(L) bde	1	1	1	6	6
Total Bdes	25	27	27	33	41
RCP	0.71	0.59	0.54	0.51	0.44

Structured force: 5 AC heavy divisions (1 2/3 fwd, 1 2/3 POMCUS)
 1 AC air assault division
 1 AC airborne division
 2 AC light infantry division
 3 RC heavy divisions
 3 AC ACRs
 2 AC separate heavy bdes

This is the risk and cost-minimized force to meet the target RCP.

f. The solution provides a heavy force with the more expensive AC brigades providing combat power in the early time periods and the less expensive RC brigades being called on when they are available in the later time periods. Forward-stationed and POMCUS units were selected to provide the required combat power in the earliest time period before strategic lift assets could get heavy forces into the theater. Light divisions supplemented what heavy divisions could be brought to bear during the early time periods.

4-16. MAJOR REGIONAL CONTINGENCY - WEST

a. This scenario involves predominantly light friendly and enemy forces facing each other in a constricted and mountainous area of operations. The theater objective is to minimize risk in a defensive operation. Therefore, the target RCP was again established as 0.6:1 (friendly/enemy).

b. The following inputs were used in the analysis:

(1) D-day = C+30.
 RC availability = C-day + 60

(2) Theater multipliers:

Allied inf div	1.00
US hvy bde (fwd)	1.25
US lt bde (fwd)	1.25
US hvy bde	.75
US inf bde	1.00
Threat inf div	1.00

(3) Friendly forces by time period:

	D-day	D+5	D+15	D+30	D+45
Inf div	25	35	40	45	50

(4) Threat forces by time period:

	D-day	D+5	D+15	D+30	D+45
Inf div	35	40	50	70	70

c. The following are the constraints used in the analysis:

- (1) Max US forward-stationed bdes: 3
- (2) Max US bdes with prepositioned equipment: 0
- (3) Max US bdes by time period (based on lift assets, unit availability, and deployment time):

	D-day	D+5	D+15	D+30	D+45
Hvy bdes	3	3	4	7	15
Total bdes	5	5	11	13	23
RC bdes	00	00	00	13	23
AA bdes	3	3	3	3	3
AB bdes	3	3	3	3	3
Lt inf bdes	6	6	6	6	6

d. Based on these inputs and constraints, the following solution was obtained:

	D-day	D+5	D+15	D+30	D+45
Fwd hvy bde	3	3	3	3	3
Reinf AC hvy bde	0	0	1	1	1
Reinf RC hvy bde	0	0	0	3	11
Reinf AC AA bde	2	2	3	3	3
Reinf AC AB bde	0	0	3	3	3
Reinf RC inf bde	0	0	0	0	1
Total bdes	5	5	10	13	22
RCP	0.52	0.60	0.57	0.48	0.60

Structured force:

- 1 AC heavy division (fwd)
- 1 AC air assault division
- 1 AC airborne division
- 3 RC heavy divisions
- 1 AC ACR
- 2 RC separate heavy bdes
- 1 RC separate infantry bde

e. The solution reflects a relatively low requirement for US forces based on the strengths of the friendly and threat forces. Forward-stationed heavy brigades were selected based on an early requirement for heavy forces to complement the comparatively light friendly forces.

4-17. MAJOR REGIONAL CONTINGENCY - EAST

a. Robust threat consisting of a mixture of light and heavy units which are fairly modernized; generally light friendly forces; generally desert terrain. The theater objective is to minimize risk in a defensive operation. Therefore, the target RCP was again established as 0.6:1 (friendly/enemy).

b. The following inputs were used in the analysis:

(1) D-day = C+30
RC availability = C+60

(2) Theater multipliers:

Allied stylized bde	1.00
US hvy bde	2.00
US AA bde	3.00
US AB bde	1.60
US 1t inf bde	1.60

Threat div	1.00
------------	------

(3) Friendly forces by time period:

	D-day	D+5	D+15	D+30	D+45
Stylized bde	25	25	25	25	25

(4) Threat forces by time period:

	D-day	D+5	D+15	D+30	D+45
Mod TD	5	5	5	5	5
Mod MRD	5	5	5	5	5
Unmod TD	5	5	5	5	5
Unmod MRD	5	5	5	5	5
Infantry div	5	5	5	5	5

c. The following are the constraints used in the analysis:

(1) Max US forward-stationed bdes: 0

(2) Max US bdes with prepositioned equipment: 0

(3) Max US bdes by time period (based on lift assets, unit availability, and deployment time):

	D-day	D+5	D+15	D+30	D+45
Hvy bdes	04	07	9	13	16
Total bdes	16	20	25	33	40
RC bdes	00	00	00	33	40
AA bdes	3	3	3	3	3
AB bdes	3	3	3	3	3
Lt inf bdes	6	6	6	6	6

d. Based on these inputs and constraints, the following solution was obtained:

	D-day	D+5	D+15	D+30	D+45
Reinf AC Hvy Bde	4	4	4	4	4
Reinf AC AA Bde	3	3	3	3	3
Reinf AC AB Bde	2	2	2	2	2
Total Bdes	9	9	9	9	9
RCP	0.49	0.54	0.60	0.60	0.60

Structured force: 1 AC heavy division
 1 AC air assault division
 2/3 AC airborne division
 1 AC ACR

e. The solution, which is a good mix of light and heavy units, reflects that deployment constraints are the key factor. Light units were selected in order to meet RCP objectives in the early time periods before more than four heavy brigades could be deployed.

4-18. LESSER REGIONAL CONTINGENCY

a. Threat consisting of light forces operating in mountainous/jungle terrain. Friendly forces are also light. The theater objective is to minimize risk in an offensive operation. Target RCP was established at 2.5:1 (friendly/enemy).

b. The following inputs were used in the analysis:

(1) D-day = C+5
 RC availability = C+60

(2) Theater multipliers:

Allied lt div	1.00
US hvy bde	1.00
US AA bde	3.00
US AB bde	1.20
US lt inf bde	1.20

Threat lt div	1.00
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(3) Friendly forces by time period:

	D-day	D+5	D+15	D+30	D+45
Lt inf div	1	1	1	1	1

(4) Threat forces by time period:

	D-day	D+5	D+15	D+30	D+45
Lt inf div	3	3	3	3	3

c. The following are the constraints used in the analysis:

(1) Max US forward-stationed bdes: 0

(2) Max US bdes with prepositioned equipment: 0

(3) Max US bdes by time period (based on lift assets, unit availability, and deployment time):

	D-day	D+5	D+15	D+30	D+45
Hvy bdes	00	00	0	03	11
Total bdes	00	03	06	09	13
RC bdes	00	00	00	00	00
AA bdes	3	3	3	3	3
AB bdes	3	3	3	3	3
Lt inf bdes	6	6	6	6	6

d. Based on these inputs and constraints, the following solution was obtained:

	D-day	D+5	D+15	D+30	D+45
Reinf AC AA bde	0	3	3	3	3
Total bdes	0	3	3	3	3
RCP	0.33	2.5	2.5	2.5	2.5

Structured force: 1 AC air assault division

e. The solution indicates the need for relatively low levels of combat power given a small light threat--the air assault division because it is a light division which can deploy quickly but still has a large combat potential relative to the other light divisions. Its mobility increases its potential through the theater multiplier.

4-19. FOLLOW-ON ANALYSIS

a. The inputs, constraints, and results presented are intended to provide the reader with a sense of how the model operates and what outputs it generates. Each theater can be viewed alone or in some combination of theaters to provide a total or summary force requirement. Of course, combinations of theaters competing for scarce or limited resources provides

the most interesting case for analysis. The requirements type of analysis was presented here because it tracked with an ongoing effort to support the Army Strategic Force Architecture (ARSTAR) Study. Not presented here, but available as direct outputs from the model, are the recurring dollar cost and manpower (AC/RC) requirements for each or any combination of the theater forces required. As an example, the total force structure and resource requirements for a combination of the AFCENT, MRC-E, and MRC-W analyses just presented is given below.

Heavy divisions	7 AC/6 RC		
Air assault divisions	3 AC		
Airborne divisions	2 2/3 AC		
Light infantry divisions	2 AC		
Total divisions	14 2/3 AC/6 RC		
ACRs	5 AC		
Heavy brigades	2 AC/2 RC		
Light inf brigades	1 RC		
Total FNDCI	7 AC/3 RC		
Personnel (thousands)	AC	RC	Total
Divisional + FNDCI	205.1	88.2	293.3
NFNDCI	86.8	79.5	166.3
TSI	123.0	170.8	293.8
Total deployable	414.9	338.5	753.4
End strength	758.4	439.7	1198.1
Recurring costs (billions) of deployable forces	\$18.24	\$4.14	\$22.38

b. While the analysis as presented can stand alone, the true extent of GLOFAM's capabilities and utility is best demonstrated by postoptimality sensitivity analysis of the relationships between key input parameters and the solution obtained. Typically, it takes about 10 minutes to change an input variable and obtain a new solution. Therefore, a whole series of runs can be executed in several hours; these runs can be used to develop relationships which can be used to determine the driving factors in the solution. As an example, suppose it is of interest to determine what the effect on the solution is of changing just one input variable--warning time. Relationships, including graphical representations, could then be developed, such as those shown in Figures 4-1 through 4-3 for AFCENT, which would show the changes in the outputs (RCPs achieved, AC/RC mix, heavy/light mix, recurring costs incurred) resulting from changing a theater warning time by some fixed increment. Varying both the warning time and the size of the threat for AFCENT could be used to produce a series of results such as are shown in Figures 4-4 through 4-6. Note that in Figures 4-5 and 4-6 the requirement for US brigades is identical because all possible US brigades are being used but lift and policy constraints prevent the target RCPs from being achieved. Also note that in Figure 4-6 the requirement for light US brigades goes to zero when warning time reaches 70 days for the 60-division threat. This is because 70 days of warning time allows deployment of sufficient heavy forces

in the early time periods to meet the target RCPs without need for light forces. The same type of analysis could be performed for changes, or combinations of changes, in the following parameters:

1. Stationing policy
2. Lift assets
3. Threat profiles
4. Allied contributions
5. AC/RC mix policy guidance
6. Heavy/light forces mix
7. Budget
8. Manpower ceilings
9. Additional theaters or nontreat driven requirements

The model is uniquely designed to address "what if" and quick reaction analysis for each of the key parameters usually associated with the force design process.

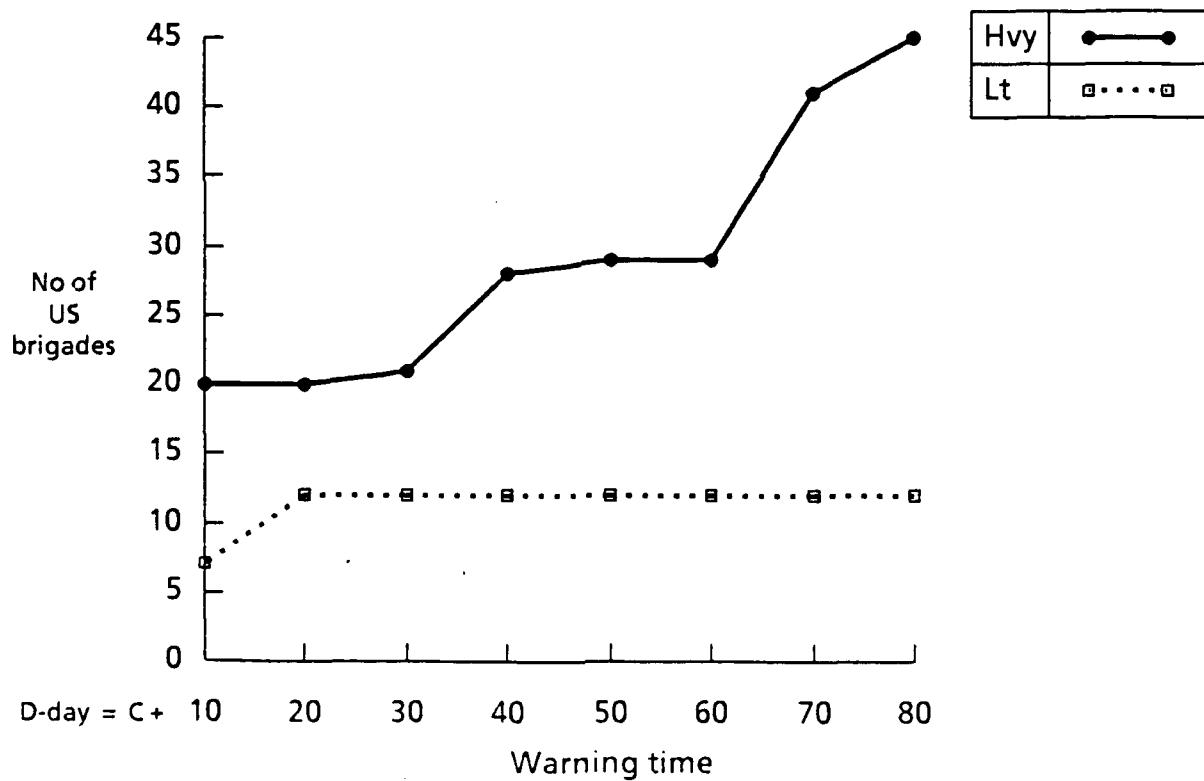


Figure 4-1. AFCENT Warning Time Variations - Heavy/Light Mix

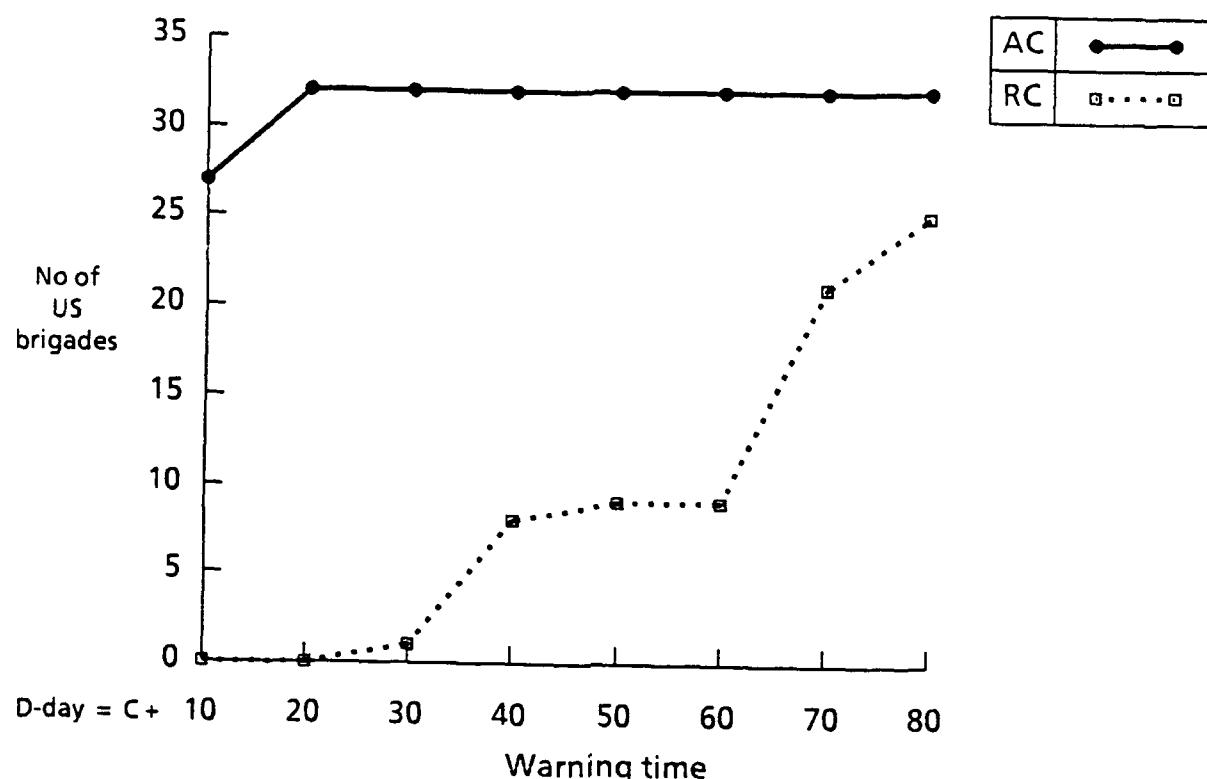


Figure 4-2. AFCENT Warning Time Variations - AC/RC Mix

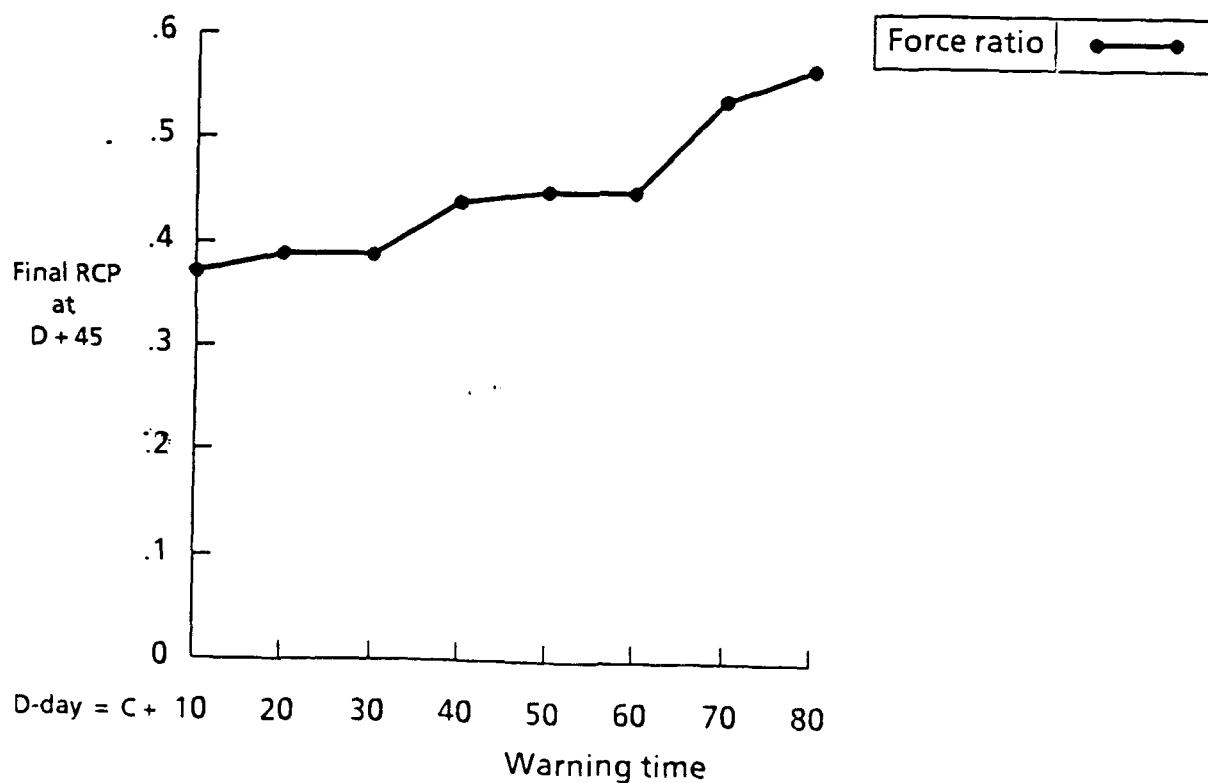


Figure 4-3. AFCENT Warning Time Variations - Final RCP

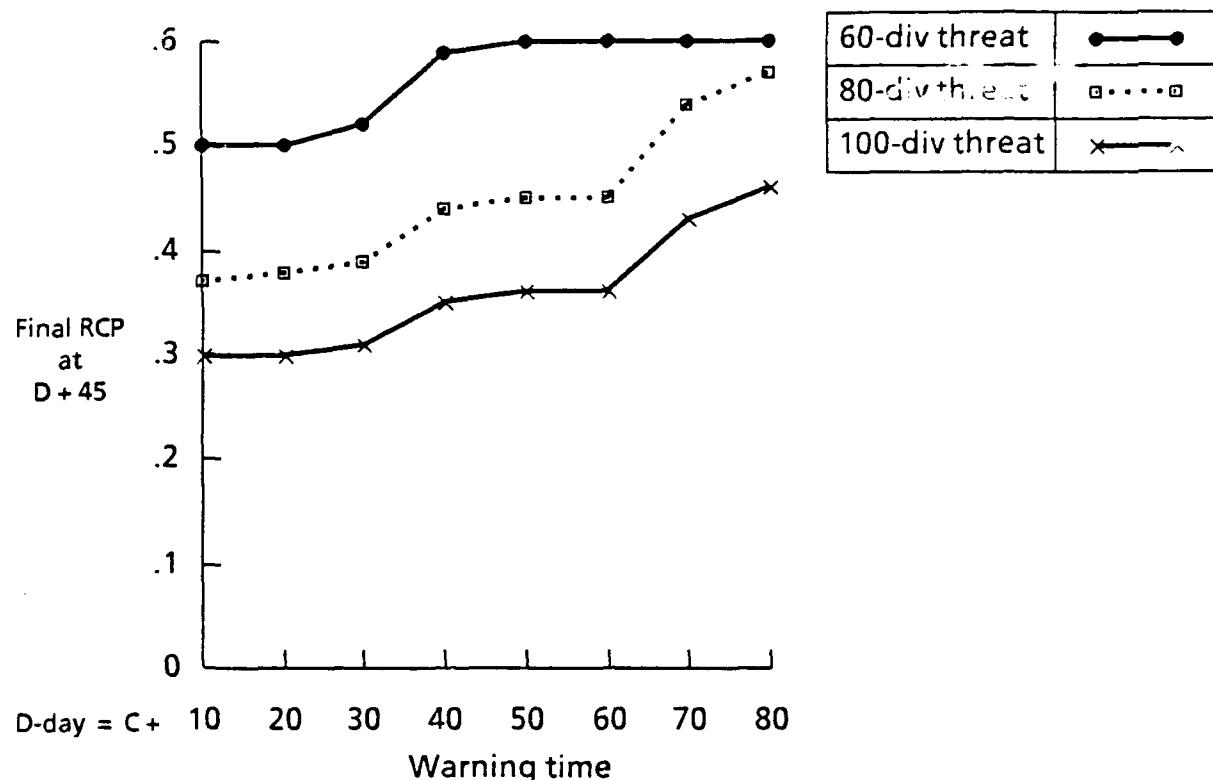


Figure 4-4. AFCENT Warning Time/Threat Variations - Final RCP

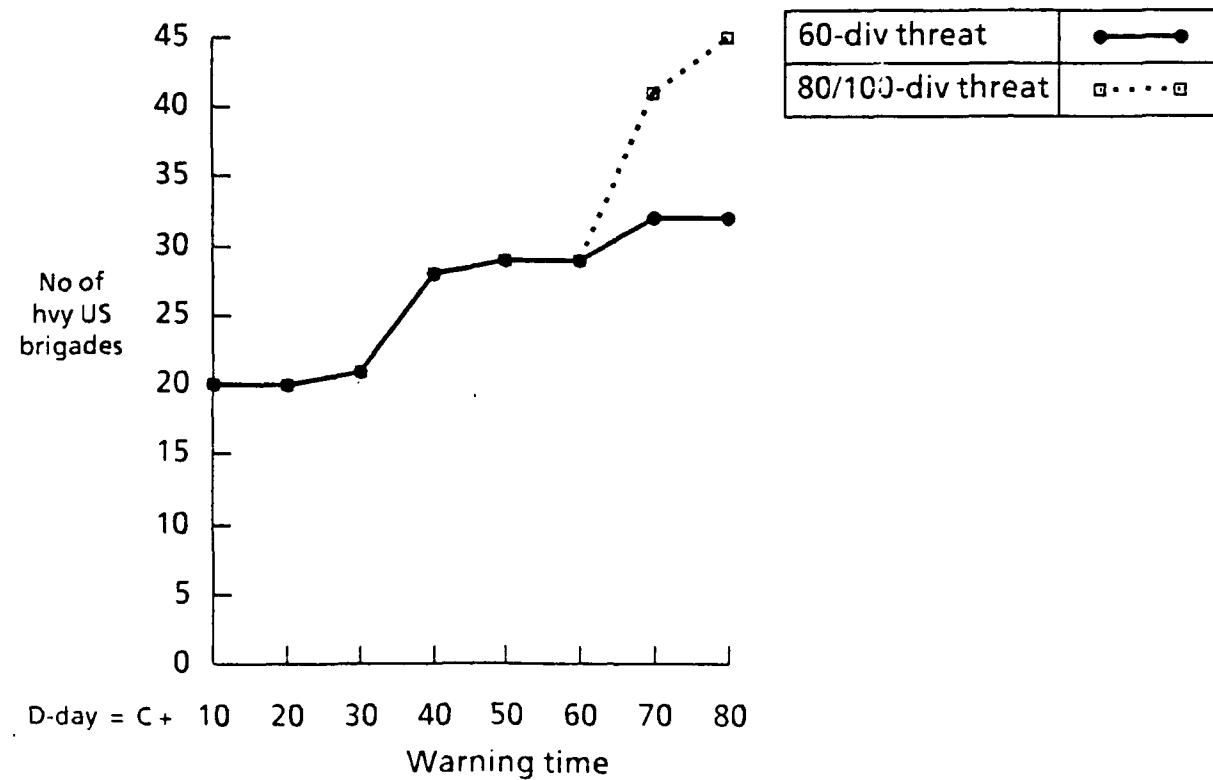


Figure 4-5. AFCENT Warning Time/Threat Variations - Heavy US Brigades

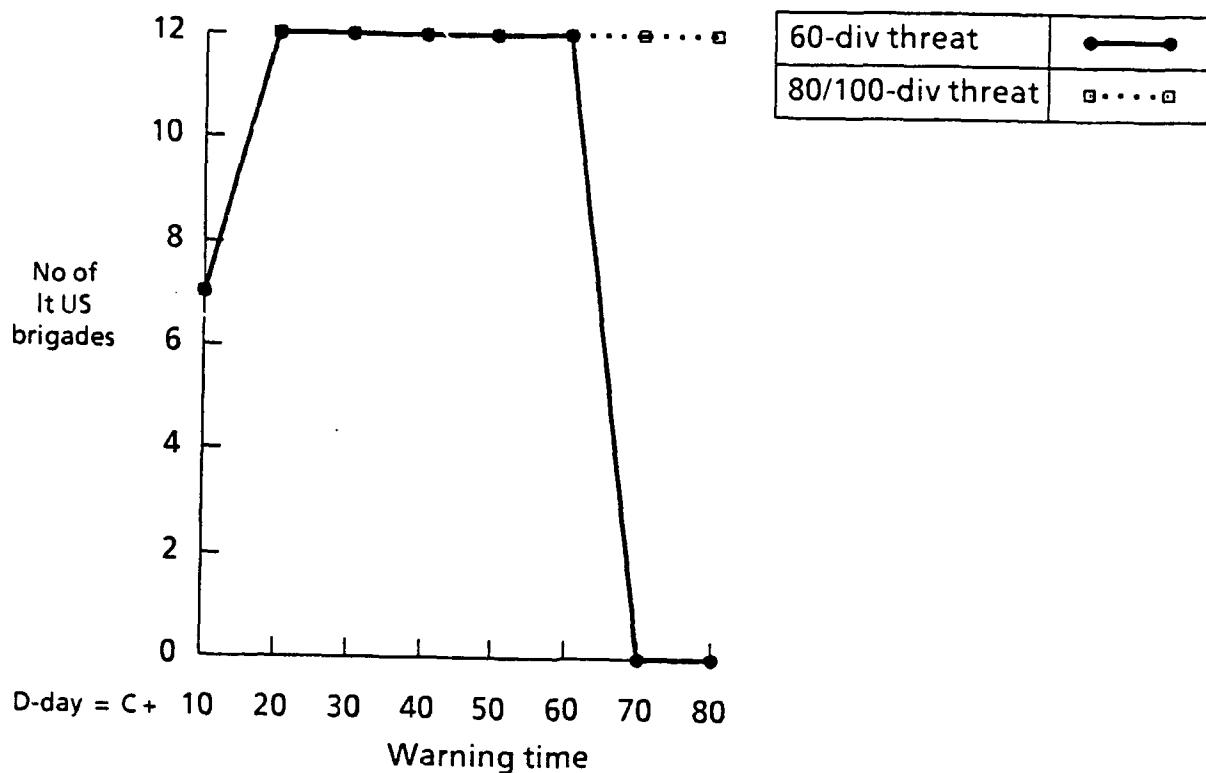


Figure 4-6. AFCENT Warning Time/Threat Variations - Light US Brigades

CHAPTER 5

SUMMARY

5-1. INTRODUCTION. This report describes the Global Force Allocation Model (GLOFAM), which was developed to address a perceived need for an analytical tool to support force planning within the revised and ever-changing demands of the current and future international security environment. The model was developed to address force sizing and allocation issues and alternatives at a macro level of analysis for a global application involving multiple theaters and/or requirements. The model was designed to be straightforward, easily adapted, fast, and useful in an environment of uncertainty concerning values, or range of values, of what are considered the basic parameters of force design.

5-2. THE LINEAR PROGRAMMING MODEL

a. GLOFAM is a linear programming model implemented in a spreadsheet format. It provides recommended force structure for given multiple constraints. The model can be formulated in two configurations as follows:

Minimize risk (shortfall from combat power objective)

SUBJECT TO:

- (1) Resource constraints (AC/RC personnel, dollars).
- (2) Unit availability and deployability.
- (3) Stationing criteria (forward-stationing).
- (4) Other policy criteria.

Or cost can be minimized subject to constraints on risk, personnel, and number of units. This formulation is as follows:

Minimize cost (dollars)

SUBJECT TO:

- (1) AC/RC personnel ceilings.
- (2) Minimum combat potential goals.
- (3) Force availability and deployability.
- (4) Stationing criteria.
- (5) Other policy criteria.

b. GLOFAM can be operated in a two-step procedure where minimizing risk is the number one priority and minimizing cost is a secondary priority. The minimum risk version is run first. The risk level achieved in the initial

run is then used as a constraint in the cost minimization routine. This procedure allows for the investigation of alternative designs which may not meet all goals for effectiveness and cost, but offers alternatives which attempt to meet the goals as closely as possible. GLOFAM produces the time-phased force requirements for multiple theaters/demands.

5-3. MODEL PURPOSE. GLOFAM was developed to be used as the main model for quick reaction analyses (QRAs) and "what if" drills, or as a screening tool prior to detailed analysis of a proposed force in a campaign simulation or wargame. Campaign simulations and wargames provide very detailed answers to specific questions about force capabilities. GLOFAM, on the other hand, allows the investigation of the potential impact of a wide range of macro-level variables on force design with greater ease and flexibility than is possible with a combat simulation. Ideally, the linear programming framework of GLOFAM and the campaign simulation modeling environment can interact synergistically in a feedback process that maximizes the value of both as shown in Figure 5-1. GLOFAM can be used as a screening tool to eliminate solutions which do not meet basic force planning requirements. Campaign simulations could be used to calibrate GLOFAM through regression analysis or other techniques such that the linear program can be used to very quickly and accurately estimate the outcome of campaign simulations.

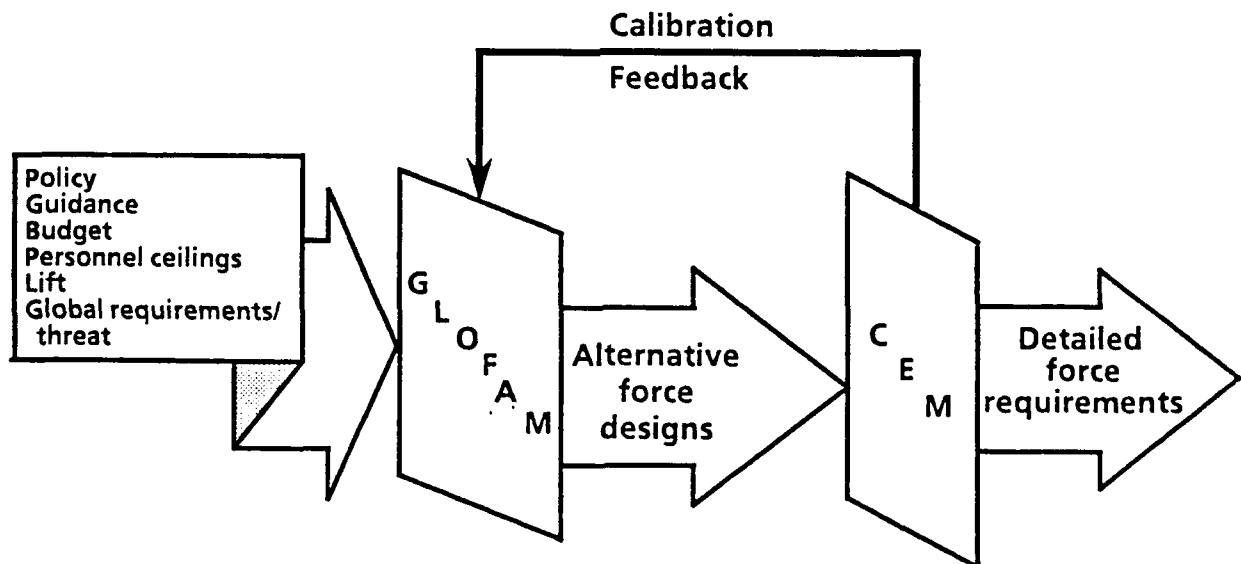


Figure 5-1. GLOFAM and the Force Development Process

5-4. MODEL DEVELOPMENT/ENHANCEMENT PLAN

a. GLOFAM became operational as a prototype in August of 1990. It is now in use in a study environment. The model is implemented in a flexible format so that space is provided for temporary constraint considerations. As an example, suppose that it was only possible to equip 10 heavy divisions. In this case, an upper limit of 10 heavy divisions for all theaters at time period $j=5$ would be imposed in order to model this condition.

b. A follow-on study effort is being planned to enhance and increase the force planning and strategic concepts which can be addressed in the model. Model enhancements and/or expansions are being considered in the following areas.

- (1) Unit/equipment combat power contributions will continue to be refined in order to further address force modernization issues.
- (2) Target values for force ratios will be refined through further collection of results of campaign simulations.
- (3) Data collection and reduction capability for model inputs will be improved to provide increased ability to perform quick turnaround analysis.
- (4) Increased resolution of combat service/combat service support definitions and addition of war reserve stocks as a force planning parameter.
- (5) Improvement of capability to model deployment/lift factors.

5-5. CONCLUSION. The intent of this report was to present GLOFAM in a straightforward, conceptual manner. This document has identified the need for a global theater model, explained a solution approach, and suggested a direction for future endeavors. A multiple theater, risk-driven model is required in the face of an uncertain future. Many sophisticated and detailed models are available for comprehensive force evaluation. Combat simulation models provide very detailed answers to specific questions about force effectiveness. The linear programming approach used in GLOFAM allows the investigation of the potential impact of a wide range of macro-level variables on force design (e.g., training, deterrence, risk, etc.) with greater ease and flexibility than is possible with a combat simulation model. GLOFAM should assist in the rapid resolution of Army long-term planning problems.

APPENDIX A
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APPENDIX B
BIBLIOGRAPHY

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GLOSSARY

ABBREVIATIONS, ACRONYMS, AND SHORT TERMS

AA	Air Assault
AB	Airborne
AC	Active Component
acft	aircraft
ACR	armored cavalry regiment
AFCENT	Armed Forces Central Europe
ALO	authorized level of organization
Ar	Armor
ARB	Analysis Review Board
Avn	aviation
Bde	brigade
BO	Base Operations
CAA	US Army Concepts Analysis Agency
C-day	commence deployment
C-rating	readiness level
CEAC	Cost and Economic Analysis Center
CEM	Concepts Evaluation Model
CONUS	continental United States
CS	combat support
CSS	combat service support
dbf	data base file
0-day	day combat begins
DAMO-SSW	Deputy Chief of Staff for Operations and Plans, Division of War Plans
DFE	division force equivalent

DI	divisional increment
Div	division
FAS	Force Accounting System
FASTALS	Force Analysis Simulation of Theater Administrative and Logistic Support (model)
FNDCI	flag nondivisional combat increment
fwd	forward
FY	fiscal year
GLOFAM	Global Force Allocation Model (study)
GSF	general support forces
HHC	headquarters and headquarters company
HQDA	Headquarters, Department of the Army
hvy	heavy
ID	infantry division
ITOE	intermediate table of organization and equipment
inf	infantry
JCS	Joint Chiefs of Staff
JSPS	Joint Strategic Planning System
LIN	line item number
LP	linear program
LRC	Lesser Regional Contingency
lt	light
mech	mechanized
Mod	modernized
MRC	Major Regional Contingency
MRD	motorized rifle division
MRFS	Mid-Range Force Study
MSLS	missiles

MTOE	modification table of organization and equipment
MX	mechanized
NATO	North Atlantic Treaty Organization
NDCI	nondivisional combat increment
NFNDCI	nonflag nondivisional combat increment
NGPA	National Guard Personnel, Army
ODCSOPS	Office of the Deputy Chief of Staff for Operations and Plans
O&M	Operations and Maintenance
O&S	Operating and Support
OCONUS	outside continental United States
OMNG	Operations and Maintenance, National Guard
OPA	Other Procurement, Army
Optempo	operational tempo
OSMIS	Operating and Support Management Information System
PCP	potential combat power
POL	petroleum, oils, and lubricants
POMCUS	prepositioned materiel configured to unit sets
PPBES	Planning, Programming, Budgeting, and Execution System
QRA	quick reaction analysis
RC	Reserve Component
RCP	relative combat power
Reinf	reinforcing
Roptempo	Reserve operational tempo
RPMA	Real Property Maintenance Account
SOF	Special Operations Forces
SRC	standard requirement code

std	standard
STF	special theater forces
TAFCS	Total Army Force Cost System
TD	tank division
TDA	table(s) of distribution and allowances
TOE	table(s) of organization and equipment
TPSNA	troop program sequence number, Army
TRADOC	US Army Training and Doctrine Command
TSI	tactical support increment
TTHS	Trainees, Transients, Holdees, and Students
UIC	unit identification code
Unmod	unmodified
US	United States
USSR	Union of Soviet Socialist Republics
WWII	World War II
WTCV	weapons and tracked combat vehicles



GLOBAL FORCE ALLOCATION MODEL (GLOFAM) DEVELOPMENT AND TECHNICAL DESCRIPTION

STUDY
SUMMARY
CAA-SR-91-15

THE REASON FOR PERFORMING THIS STUDY was to provide the Army with a new analytical tool to support force planning by the Army Staff within the revised demands of current and future international security environments.

THE STUDY SPONSOR. This was an internal US Army Concepts Analysis Agency (CAA) research and development effort.

THE STUDY OBJECTIVE was to develop a flexible, fast-running, easy-to-understand model which will provide recommended force structures for multiple global requirements within imposed resource, policy, and other constraints.

THE MAIN ASSUMPTIONS of this work are:

- (1) The results of campaign simulations using the Concepts Evaluation Model (CEM) can be used to calibrate an effectiveness parameter in a linear programming model to provide an indicator of force performance.
- (2) Simple, effective, and acceptable techniques can be used to determine the contribution of weapon systems and land forces, including combat support (CS) and combat service support (CSS), to theater-level campaign simulations.

THE BASIC APPROACH used in this study was to develop a spreadsheet-based linear programming model which is flexible, fast-running, and user-friendly, and which addresses the essential elements and parameters of the force planning process.

THE PRINCIPAL ACCOMPLISHMENT of this work is the development of a force planning analytical tool which can be used as:

- (1) A screening tool prior to detailed analysis by campaign simulation, or other means, when time permits.
- (2) The main model for quick reaction analyses and force planning during periods of uncertainty.

The model can provide recommended force structure for:

- Given resource levels (manpower, money, lift, equipment).
- Given strategic objectives.
- Incorporation of modernized weapon systems and new force concepts.
- Support elements.

THE STUDY EFFORT was directed by MAJ John Dovich, Strategy and Plans Directorate.

COMMENTS AND QUESTIONS may be sent to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-SPF, 8120 Woodmont Avenue, Bethesda, Maryland 20814-2797.